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ESTIMATING EVAPOTRANSPIRATION (III) FROM SOLAR RADIATION

by

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FOREWORD

A number of empirical equations and equations based upon physical principles have been developed for estimating potential evapotranspiration. The relationships developed are generally applicable only when a complete crop cover exists and when there is an ample supply of soil moisture. Furthermore, similar conditions for large areas surrounding the crop site in question may be required for valid use of potential evapotranspiration equations developed in humid areas.

Potential evapotranspiration estimates have limited utility for practical application under arid and semiarid conditions. In some instances, estimating procedures have been developed under humid conditions, and when applied to Western conditions, tend to underestimate potential evapotranspiration in irrigated areas surrounded by drier, more arid areas. The problem is further complicated by annual crops that do not have a complete cover throughout the season and may not require an abundance of available soil moisture at all stages of growth. Under such conditions, estimating procedures to predict evapotranspiration, particularly for relatively short periods of water use, have not been too successful.

One reason for the inadequate evaluation of present evapotranspiration procedures in the West has been the lack of reliable published data pertaining to evapotranspiration rates for various stages of crop growth. The study herein reported was initiated to summarize and make available for general use unpublished evapotranspiration data for a variety of crops and to analyze all available data with the hope of developing a simple estimating procedure using solar radiation data available from the U. S. Weather Bureau. Much of the tabulated data herein reported and used may also be helpful in evaluating and refining other theoretical equations with the ultimate goal of developing a useable and accurate procedure to estimate evapotranspiration for use by engineers, irrigation project managers and farm operators on irrigation projects.

This study was initiated in April 1960 when a questionnaire and data sheets were sent to all personnel in the former Western Branch of the Soil and Water Conservation Research Division, USDA, who had collected evapotranspiration data. In many instances, the data were a byproduct of more complex experiments on soil-water-plant relationships. Requests for evapotranspiration data also were sent to Western Branch personnel formerly in the Division of Irrigation, Engineering and Water Conservation, Soil Conservation Service, USDA, where data were available and could be summarized from existing records.

The following individuals prepared and submitted data, much of which had not been published: Arizona--K. Harris, Phoenix; C. H. M. van Bavel, L. J. Erie, and O. F. French, Tempe. California--P. R. Nixon and G. P. Lawless, Lompoc; H. F. Blaney, Los Angeles; N. A. MacGillivray, V. S. Aronovici, E. S. Bliss and L. Gladon, Merced.

Colorado--A. L. Black and B. W. Greb, Akron; S. Davis, Grand Junction. Idaho--C. H. Pair, Boise. Montana--P. L. Brown, Bozeman. Nebraska--N. P. Swanson, Lincoln; O. W. Howe, Scottsbluff (Howe also summarized the data of L. Bowen, formerly at Scottsbluff). Nevada--R. Tovey, Reno. North Dakota--C. W. Carlson, R. H. Mickelson, J. Alessi, and H. J. Haas, Mandan. South Dakota--N. A. Dimick, B. Baird, and J. J. Bonneman (So. Dak. Agric. Exp. Sta.), Newell. Texas--E. Burnett, Big Spring; M. E. Jensen, W. H. Sletten, J. J. Bond and O. R. Lehman, Bushland; J. E. Adams, Temple; P. E. Ross, M. Amemiya, L. N. Namken and J. W. Boykin, Weslaco. Utah--L. S. Willardson, Logan. Washington--S. J. Mech, Prosser (Mech summarized the data of H. G. Nickle, formerly at Prosser).

This preliminary report does not contain a complete analysis of the data available. Hence, the data presented can only be considered as tentative and subject to change after all data are considered. A comprehensive publication will follow presenting greater detail, particularly pertinent supporting evidence from published literature.

Appreciation is expressed to numerous individuals who have contributed to the summarization of the evapotranspiration and solar radiation data. Particular gratitude is due Carol Crockett who has for the past 5 months made most of the computations, Marjorie Erdley who initially cataloged all of the data as it was collected, Carolyn Holland who transferred much of the raw data to working sheets and made preliminary computations, and to Myrtle Anderson and others on the office staff at Fort Collins for typing and mimeographing this preliminary report.

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ESTIMATING EVAPOTRANSPIRATION FROM SOLAR RADIATION[1/]

by

Marvin E. Jensen and Howard R. Haise[2/]

INTRODUCTION

During the past few years, an intensive effort has been directed toward obtaining evapotranspiration (E_t) rates throughout the season for various crops as a result of a demand for this information. These data are needed by the irrigator for scheduling irrigations; the system designer for planning more efficient distribution systems; the project manager for evaluating storage requirements, predicting delivery rates in advance, and better allocation of limited water supplies; and the project planner and designer for better predictions of irrigation water demands in relation to supplies and the functioning of the project irrigation distribution system during an irrigation season.

Studies of irrigation water requirements for entire river basins are underway. These studies frequently involve estimating E_t for various crops throughout the growing season and comparing these estimates to diversions and rainfall that occurred during specific years in the past. Such studies may modify water allocations in the future for more effective use of limited water supplies. Therefore, accurate estimates of E_t for short periods of time are needed because unreliable estimates make such studies futile and can result in serious legal litigations. Projects will be more costly because most of the irrigable land that can be developed at low cost has been developed. Therefore, greater precision in estimating E_t rates throughout the season with smaller safety factors will be needed to make more efficient use of water and to make new projects economically feasible. The capacity of drainage systems also may be reduced if better estimates of E_t are available.

Recent studies of the principles of evapotranspiration have definitely shown that direct input of energy to the soil surface and the crop and the partitioning of this energy can be measured with sufficient accuracy to predict resulting evapotranspiration with a relatively high degree of accuracy, Pelton et al., (1960), and Tanner (1960). However, these measurements require elaborate instrumentation, specialized training, and are not readily adaptable to the solution of practical problems facing the irrigation engineer and irrigationist. Designers in most instances

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1/ Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.

2/ Investigations Leaders, Water Management, Northwest Branch and Northern Plains Branch, respectively, Fort Collins, Colorado.

must rely on readily available information to estimate E_t for a proposed project. The individual irrigator frequently guesses when irrigations are needed even though a number of relatively inexpensive soil moisture instruments are available commercially.

This study has two principal objectives: first, to summarize and make availalbe a large quantity of unpublished E_t measurements for various crops at many locations, and, second, to investigate the possibility of utilizing solar radiation instead of temperature as a parameter for estimating E_t. Although temperature has been used in empirical approaches to estimate seasonal E_t with reasonable accuracy, it represents only a small part of the energy exchange that occurs and cannot be expected to give reliable estimates of short-term water use. Solar radiation, on the other hand, offers the use of a physical measurement directly associated with energy available for evapotranspiration. Use of solar radiation instead of temperature offers the possibility of improving accuracy of short term E_t estimates and in the development of simplified estimating procedures.

MEASURED EVAPOTRANSPIRATION RATES

Evapotranspiration (E_t), defined as the sum of the volume of water transpired plus that evaporated from the soil or plant surfaces from a given area divided by that area, has received considerable attention during the past 35 years. Measurements of E_t on various crops initially were limited almost entirely to seasonal use. More recently, data reported has included both seasonal and peak use rates with additional rates often presented in graphical form but usually lacking detail needed for tabulating short-term E_t rates. Some of the original data were a byproduct of irrigation management studies and required retabulation and computations to place it in a useable form. In many instances, the data were of limited value because of inadequate sampling techniques and procedures or faulty irrigation practices. Nonetheless, the estimated investment in the E_t data collected and considered reasonably reliable is placed between 1 and 2 million dollars. Further refinements in measurement of E_t may be needed ultimately for better evaluation of estimating procedures; however, the data being summarized in this study represent a large portion of measured E_t data available today in the Western United States.

As mentioned in the Foreword, much of the short-term E_t data have not been published and were solicited from the former Western Branch personnel. The request sent to field locations consisted of two data sheets. One sheet was to be completed for each experimental site and crop studied. The second sheet contained specific data for each crop-year.

Collection of E_t Data

Examples of data sheets sent to each contributor are in appendix B. In general, information requested included location, crop, variety, rooting depth, soil moisture characteristics, water table depth, irrigation method, size of plot or field sampled, description of surrounding area and personnel responsible for measurements. For each crop-year, data included number of places sampled, irrigation treatment (optimum or medium), planting date, harvest date, fertilizer used, yield (normal or below), and variability of E_t measurements (standard deviation per sampling place).

Each measurement of E_t reported was also supported by information pertaining to the following:

<u>Irrigation</u> - number in the season, date and depth applied

<u>Soil sampling procedure</u> - dates sampled, number of places sampled and sampling depth

<u>Climate</u> - average maximum and minimum temperature, rainfall, wind movement, evaporation, general climatic conditions

<u>Crop</u> - stage of growth, approximate plant height

<u>Evapotranspiration</u> - actual measured values, estimates following irrigations and cumulative E_t.

In many cases, all details indicated above were not available and in some instances pertinent facts were missing. Where adequate information was not supplied, data were placed in a questionable category. Published data from State experiment stations were also summarized if essential detail was given.

Preliminary Screening of E_t Data

Each experimental site was evaluated for measurement procedure and data available using the following arbitrary standards:

Item	Satisfactory	Useable with care	Questionable
Water table	$>$8 feet	4-8 feet	$<$4 feet
Location of site	In irrigated area	Surrounded by some dry land	Isolated plot
Planting and harvest dates	Given	Estimated	Not given
Normal yield	Yes	Reduction due to known cause	Below normal
Places sampled	$>$4	3	$<$3
Depth sampled	4-6 feet	3-4 feet	2-3 feet

Other factors such as temperature, wind movement, evaporation, stage of growth, plant height and growing season for forage crops also were considered.

After evaluating general site conditions and methods of measurement, each sampling period was then placed in a satisfactory or questionable category according to the following arbitrary standards:

Item	Satisfactory	Questionable
Depth of the preceding irrigation	Normal	Excessive (possible continued drainage)
Date of 1st sampling after irrigating	$>$2 days after irrigating	$<$2 days after irrigating
Length of sampling period	7-14 days preferred	$<$5 days
Rainfall	Light showers	Heavy rainfall

After preliminary screening, there were data for 250 location-crop-years, 1900 sampling periods ranging from 5 to 30 days, and 25 different crops available for analysis.

Final Evaluation

Final evaluation of all data has not been completed at this time. All of the preliminary calculations required are made and if final computations cannot be completed because of a lack of key supporting data, some additional values will be eliminated. As each value is plotted, it is rechecked to see if it meets the primary requirements of having been made on a field or plot irrigated adequately prior to the period of measurement, the first sampling was made after a sufficiently long period of time after an irrigation so as to minimize deep percolation, and rainfall was not excessive so as to cause deep percolation during the sampling period. Only actual measured values and no estimates are being used.

SELECTION OF METEOROLOGICAL AND CROP PARAMETERS

Meteorological and crop parameters are needed to permit E_t measurements to be used for estimating purpose in the future and for adapting the E_t data to other areas. Meteorological parameters must be available from records of the U. S. Weather Bureau at desired locations and in sufficient quantity for correlation purposes. Furthermore, a minimum number of parameters closely associated with potential E_t ~~are~~ desired to impart simplicity and ease of use. Temperature measurements have been widely used in the past because temperature data are available in most areas. Procedures for estimating seasonal E_t using mean temperatures have been reasonably successful and accepted.

The crop parameter must reflect the stage of growth, in particular the development of vegetative cover. Also a crop parameter must be useable for variable planting and harvest dates within a region.

Meteorological Parameters

Recent studies indicate that potential E_t is most closely associated with net radiation -- Budyko (1956), Pelton, et.al. (1960), Tanner (1960), van Bavel (1956). Although desirable, net radiation is not readily available and is not easily estimated. Also since net radiation will vary with climate, soil, crop and irrigation practice, a large number of measurements would be needed for all areas and crops. Potential E_t, on the other hand, should be closely

associated with solar radiation (short wave, 0.3 to 3 microns) since net radiation is generally about 0.5 to 0.6 of solar radiation for growing crops.

Some discussion is justified as to why temperature is not a satisfactory single climatological parameter to use for estimating E_t for periods of a week to a month. As previously mentioned, E_t is most closely related to net radiation which in turn is closely associated with solar radiation. Temperature is directly associated with only a small segment of the energy exchange or that portion of radiant energy devoted to heating of the air. Therefore, unless temperature is closely related to net radiation or solar radiation, temperature cannot be considered as a satisfactory single climatic parameter for estimating E_t, (Pelton, et.al. - 1960).

The relationship between the 9-year average maximum temperature and solar radiation for an entire year at Grand Junction, Colorado, is presented in figure 1. 1/ Maximum temperatures are more closely related to solar radiation than mean temperatures. Note the curves closely parallel each other from January to July but a cross-over occurs early in July due to the lag in temperature. Empirical procedures could be developed to compensate for the temperature lag, but if the lag is disregarded, mean temperature alone would result in two estimates of E_t for a given amount of solar energy, one for the spring, and one for the fall (figure 2). It should be pointed out that the cyclic effect of temperature as related to solar radiation would result in a slight compensating effect when used for estimating E_t. During spring months more solar energy is used in heating the soil while in the fall, heat is released from the soil under similar moisture regimes. Also the potential for advected energy would be greater for irrigated fields in semi-arid areas during the fall months because there would be less available soil moisture in the surrounding area.

When comparing mean temperature with solar radiation for a month, (figure 3) temperature could be used to adjust estimates of average E_t for locations differing substantially in solar radiation. However, if temperature is to be used as the only climatic factor for a given month and location, then correlation with solar radiation will be low as in September at Grand Junction and Bismarck and practically non-existent in April at Bismarck and Phoenix. Correlation of mean temperature and solar radiation for periods of 1 week, (figures 4, 5 and 6) is practically nil in April and very poor in September at Bismarck and Grand Junction.

1/ Since all figures were initially prepared using the term gm.cal/cm^2-day, this term will be used throughout this report. Gm.cal. was used to differentiate between calories/cm^2-day and Kg.cal/cm^2-day used by some authors.

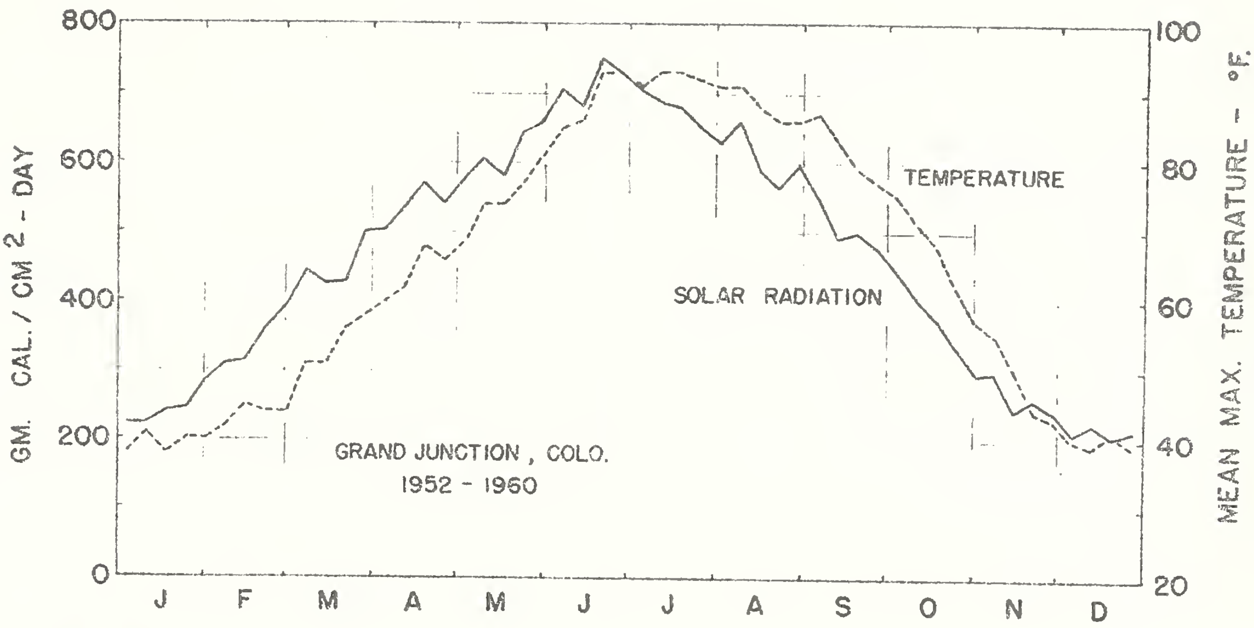

Fig. 1--Mean solar radiation (gm.cal./cm^2-day) and mean maximum temperature at Grand Junction, Colorado (1952-1960). Curves are plotted from mean weekly values.

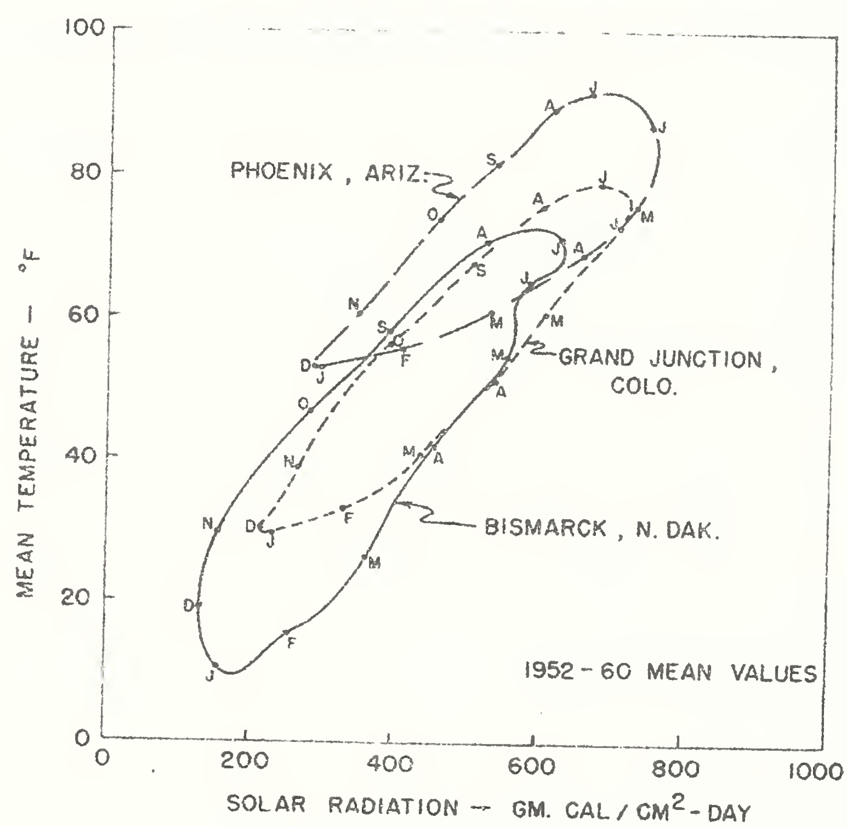

Fig. 2--Mean temperature (°F) as related to mean solar radiation illustrating cyclic effect due to higher temperatures in fall than in spring for a given amount of solar radiation at Bismarck, North Dakota; Grand Junction, Colorado; and Phoenix, Arizona (1952-1960).

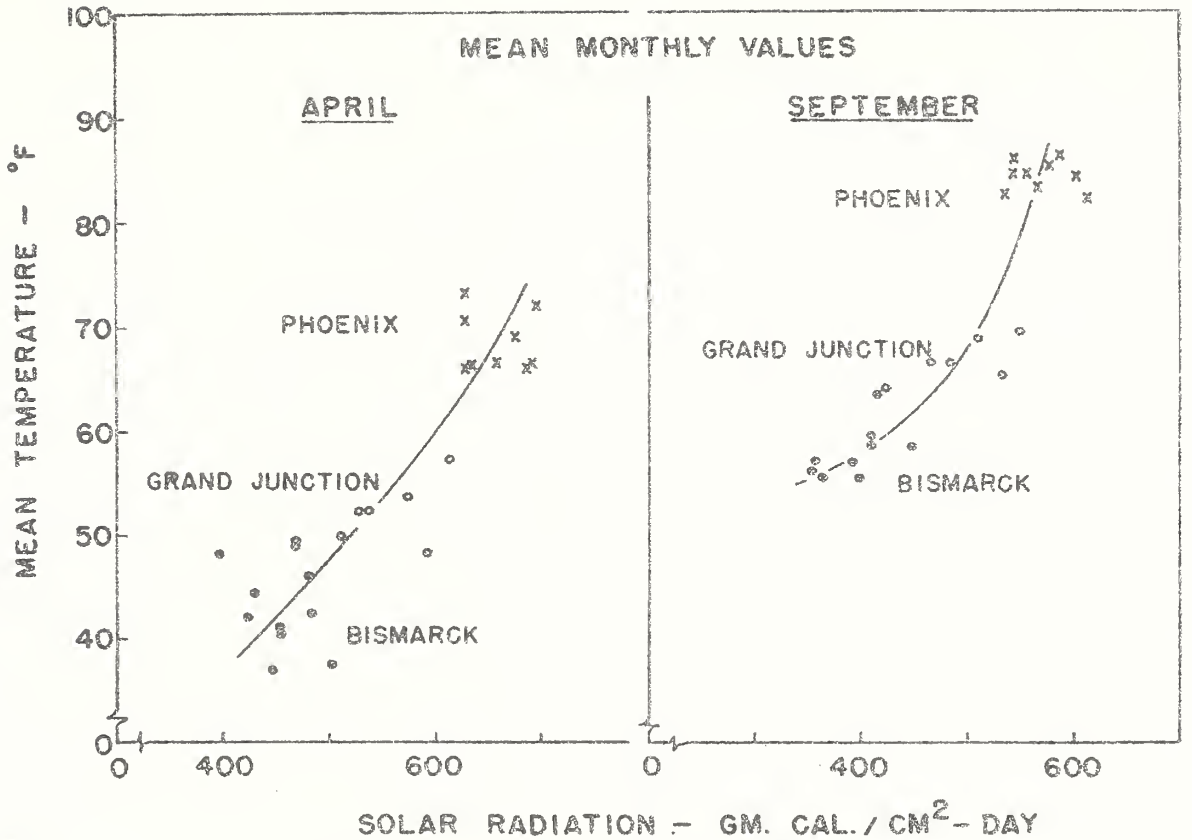

Fig. 3--Mean monthly temperature (°F) as related to solar radiation in April and September at three locations (1953-60).

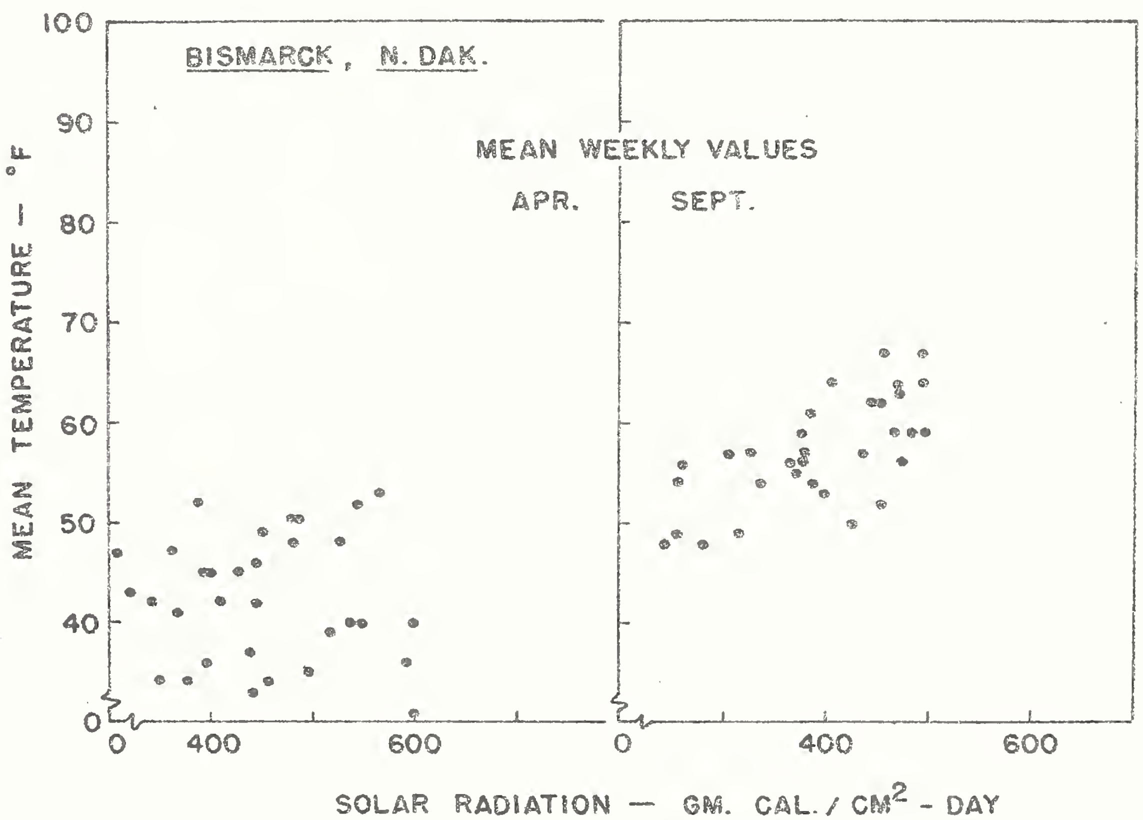

Fig. 4--Mean weekly temperature (°F) as related to mean weekly solar radiation in April and September at Bismarck, N. Dak. (1953-60).

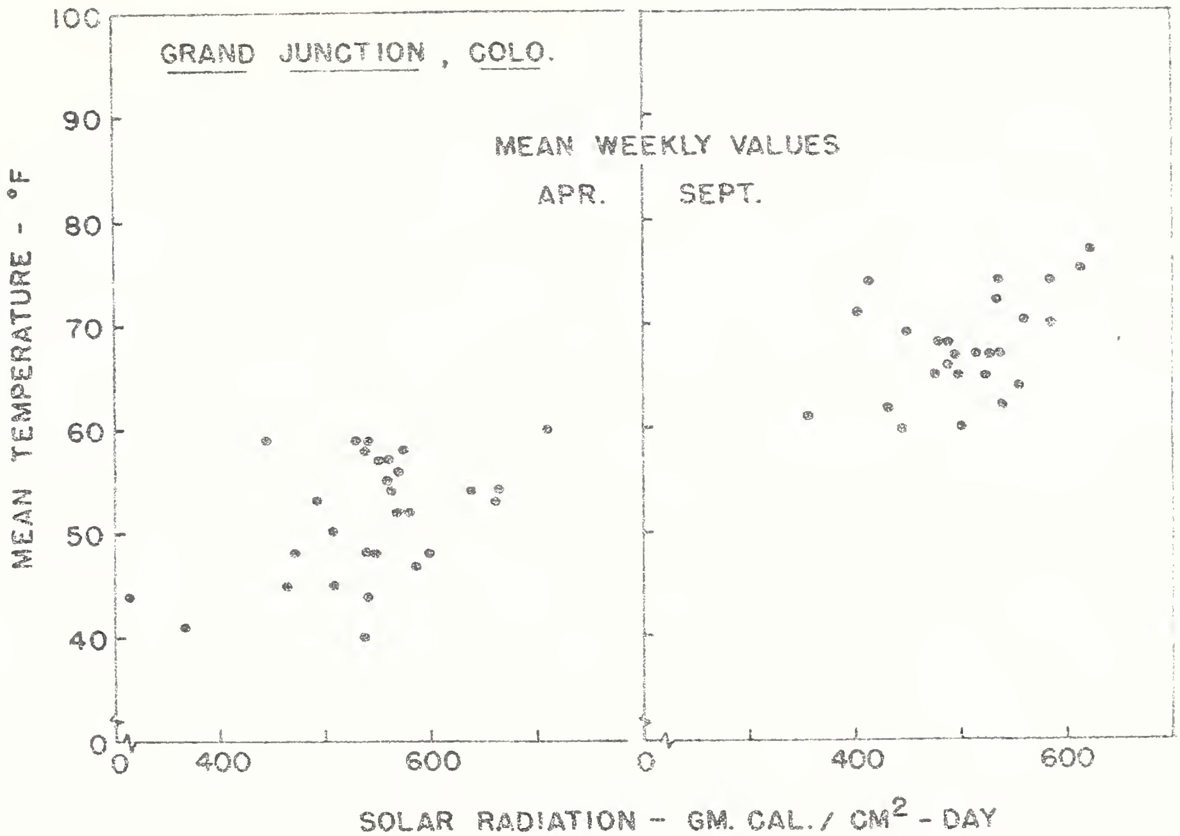

Fig. 5--Mean weekly temperature (°F) as related to mean weekly solar radiation in April and September at Grand Junction, Colo. (1953-60).

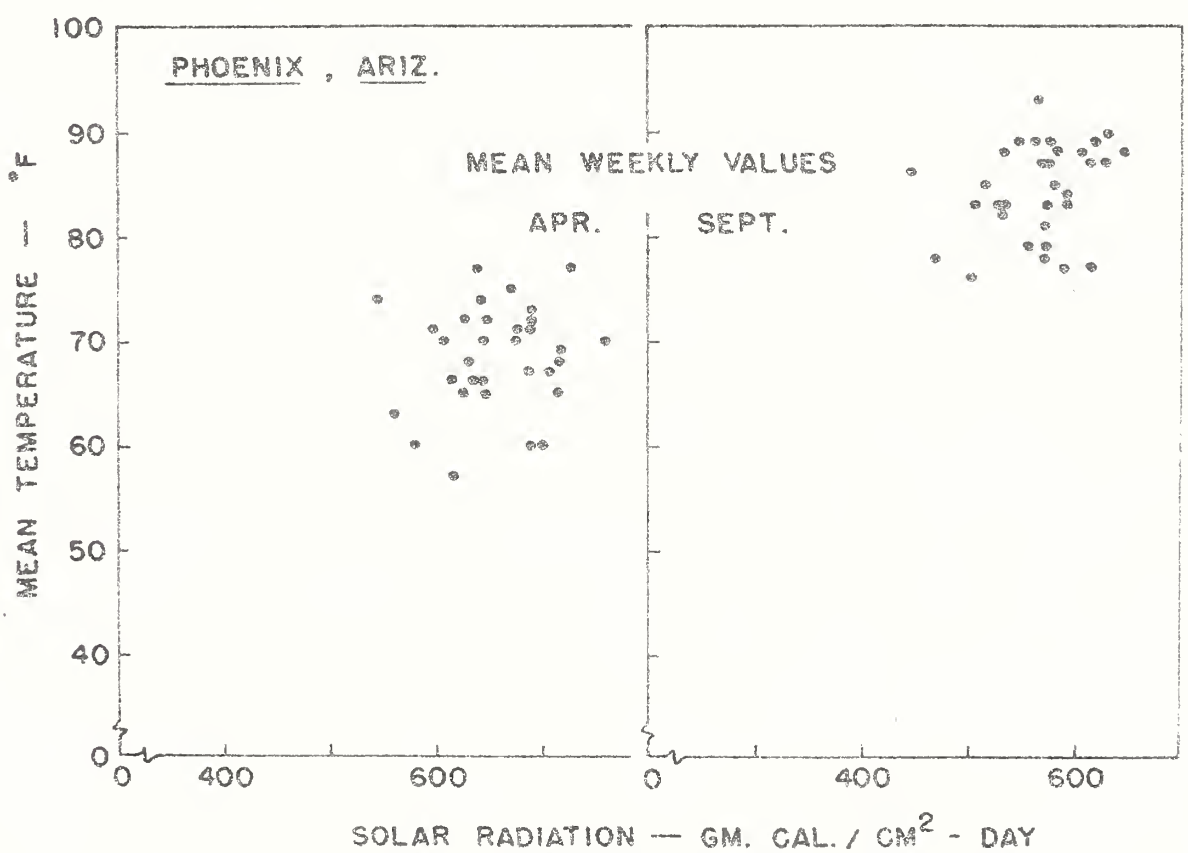

Fig. 6--Mean weekly temperature (°F) as related to mean weekly solar radiation in April and September at Phoenix, Arizona (1953-60).

There are several reasons why correlation of mean monthly temperature and solar radiation is better at Grand Junction and Bismarck in September. Mean monthly or weekly solar radiation is more variable at these two locations than at Phoenix and there is generally less available soil moisture in the area in September than in April. Consequently a greater proportion of net radiation in the region is used in heating the air and when solar radiation changes materially temperature also changes. Another reason for the very poor solar radiation-temperature relationships in April at Bismarck and Grand Junction are the cold fronts that move across the continent which are often followed by cold clear weather when solar radiation is high and temperatures low.

When considering the data presented in figures 1-6, it becomes obvious that using temperature as the prime climatic factor for estimating E_t at a given site and for a given week or month would not result in reliable estimates. This has been clearly illustrated by Pelton, et.al. (1960) when they used Thornthwaite's procedure to estimate E_t for alfalfa-brome grass hay at Hancock, Wisconsin and obtained a correlation coefficient of only 0.3 for 6-day mean values of estimated E_t and measured E_t.

Crop Parameters

Crop parameters are needed in an equation or equations for estimating E_t to adjust for differences among annual crops like corn and sugar beets, perennial crops like grasses and legumes, and evergreen and deciduous orchard crops. Similar evapotranspiration rates may occur within each of the three groups for some crops. Large differences can be expected between groups and within a group such as between a short-season grain crop and sugar beets. Potential E_t in itself is not adequate because potential E_t may be approached for only a portion of each crop season. Variations in E_t from potential E_t are great and knowledge of rates or a means of estimating E_t rates for all crops throughout each crop season is needed.

Annual crops generally have three rather distinct stages of growth that influence E_t rates. These stages are (1) emergence and development of complete vegetative cover during which time E_t increases rapidly from a low value and approaches potential E_t; (2) the period of maximum vegetative cover during which time E_t may be near or at potential E_t if abundant soil moisture is available; and (3) crop maturation where E_t begins to fall below potential E_t except for crops like sugar beets which may have an E_t rate close to potential E_t until harvest. During the maturation period the plant becomes the limiting factor in transpiration rate although a lack of available soil moisture near harvest which is a frequent occurrence on many crops may have major effects in lowering E_t below potential E_t.

During the first stage of growth E_t can also be increasing as potential E_t is decreasing. This situation occurs with short-season crops such as field beans planted late in the season after maximum potential E_t has occurred. Time of planting and harvest of a given crop may vary considerably in a region and at a given location. Also farmers sometimes replant because of poor stands resulting in widespread variations in planting dates. In order to correlate solar energy with E_t rates for a given crop over a wide area and at a given location, periodic growth stages such as indicated above were combined and expressed as percent of the crop season. This procedure made possible the adjustment of growing periods to a common base for correlation purposes.

Expressing the growing period on a calendar basis is not satisfactory because of the variations mentioned above. The growing period could have been indicated as days after planting. However, a late planting generally results in more rapid development of crop cover because of warmer soil and air temperatures. This is compensated for, to a certain extent, if percent of crop season is used since the season will be shorter.

The growing season for grasses and alfalfa was assumed to begin and end when the mean air temperature in the spring and fall reached and remained above 43° F. whereas the calendar year was used for evergreen orchard crops and other crops that are grown year-round. Frost free period will be used for deciduous tree crops in northern areas. The calendar basis will be used for deciduous orchard crops in southern areas.

Other Formulae for Estimating E_t

No attempt will be made to compare estimating procedures to be developed and given in this preliminary report to other equations. Nevertheless, use of solar radiation to estimate potential E_t or evaporation from water surfaces is not new. Makkink (from Rijtema, 1958) developed a formula in 1957 for average monthly potential E_t at Wageningen, Netherlands. This formula is as follows:

$$E_p = 0.61\, R_m \frac{\Delta}{\Delta + \gamma} - 0.12 \qquad (1)$$

where

E_p = potential evapotranspiration

R_m = measured solar radiation in mm/day

Δ = slope of temperature - vapor-pressure curve (the same as used in Penman's formula)

γ = psychrometer constant = 0.49 mm Hg./degree centigrade

This formula is limited to potential evapotranspiration and to a local area.

Richardson (1931) proposed using solar radiation in an energy balance equation to estimate evaporation from lakes. Values for sensible heat, back radiation, and Bowen's ratio were to be computed. Crabb (1952) illustrated a close correlation between mean solar radiation and mean evaporation from a "black-pan evaporimeter". However, in the figure presented a lag occurs similar to temperature lag shown in figure 1. Crabb also refers to formulae for computation of evaporation based on solar energy that have been applied by Cummings (1936), Bowen (1926), and McEwen (1930).

ENERGY BALANCE

The energy balance concept is the basis for selecting solar radiation as the main meteorological parameter in this study for estimating E_t. Factors involved in the energy balance include solar radiation, thermal radiation, evapotranspiration, sensible heat (in air and soil), net photosynthesis and storage of heat in the vegetated zone. Certain simplifying assumptions were necessary in developing the E_t estimating procedure.

Solar Energy (Short Wave)

A portion of the radiant energy from the sun is reflected back from the atmosphere and clouds as illustrated in the simplified diagram shown in figure 7. Most of the solar energy received at sea level occurs between wave lengths from 0.3 to 1.0 micron. However, the solar radiation spectrum at sea level varies from 0.3 to about 3 microns. Water vapor, ozone, and carbon dioxide absorb some of the short wave radiation at various wave lengths ranging from 0.2 to about 2.8 microns (Sanderson and Hulburt, 1955, and Gates, 1959). The glass in the bulb of Eppley pyrheliometers used by the U. S. Weather Bureau has a relatively constant transmittance up to about 2.8 microns and a reduced transmittance to about 4.0 microns (MacDonald, 1951). Therefore, pyrheliometer measurements made by the U. S. Weather Bureau represent total short wave solar radiation from direct sunlight plus scattered and reflected sky radiation. Solar radiation variations are caused by smoke, dust, haze and clouds (Brooks, 1955). The term solar radiation as used in this report includes total solar and sky radiation (0.3 to 3.0 microns) but not long wave thermal radiation from the atmosphere ($>$ 3 microns).

Upon reaching the earth's surface, a portion of the short wave radiation is reflected back to the atmosphere and space. The fraction that is reflected is called albedo, reflectance, or reflection coefficient (r) (α in figure 7 is used in place of r). The reflectance of the land surface changes during the day with the angle of the sun, a greater value occurring in the morning and evening hours (Budyko, 1956). The reflectance also changes with wave length and for water surfaces is usually much less than for land surfaces. A summary of reflectance and long wave emittance values for natural surfaces are presented in table 1. Additional values of reflectance for water surfaces can be found in Budyko, table 6, p. 40 (1956).

Thermal Radiation

All surfaces lose energy by long wave radiation according to the Stefan-Boltzmann law:

$$\epsilon \sigma T^4 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

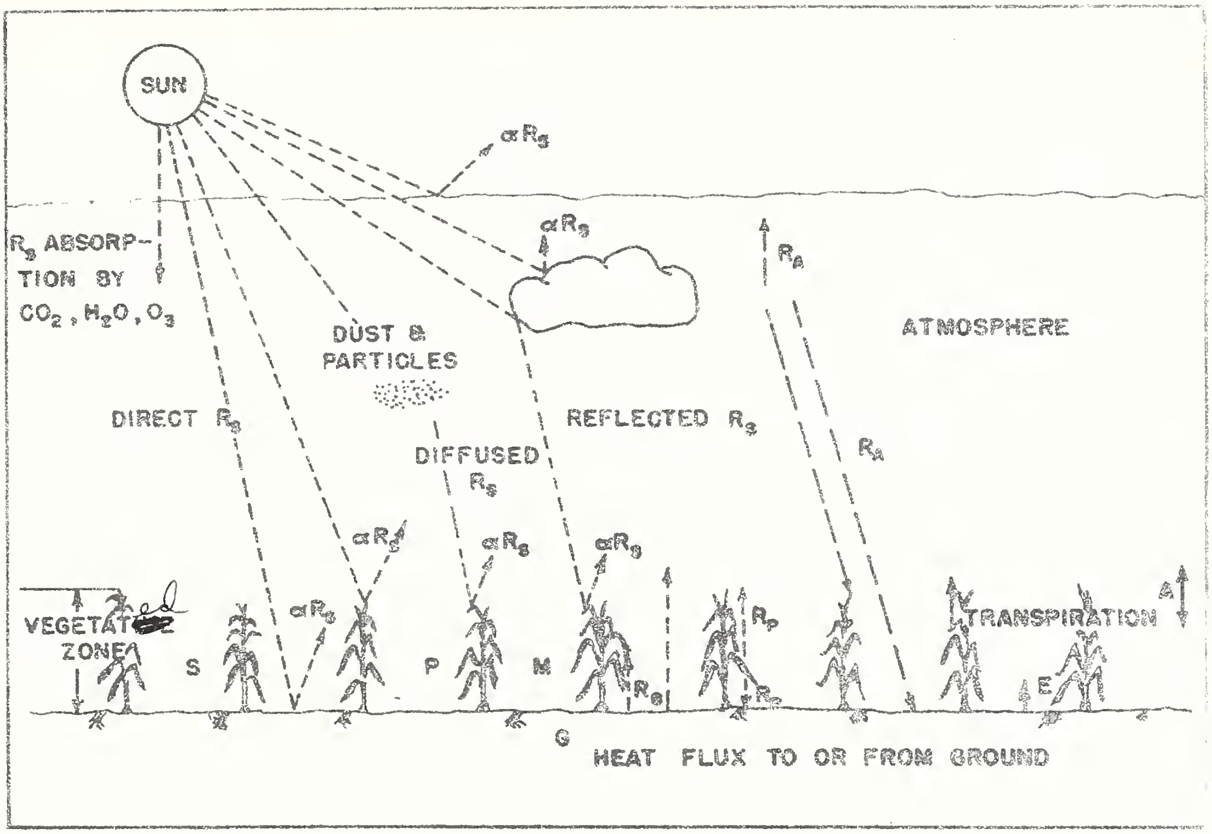

Fig. 7--Diagrammatic sketch showing disposition of solar radiation in atmosphere and at earth's surface. (See section on Energy Balance for symbols)

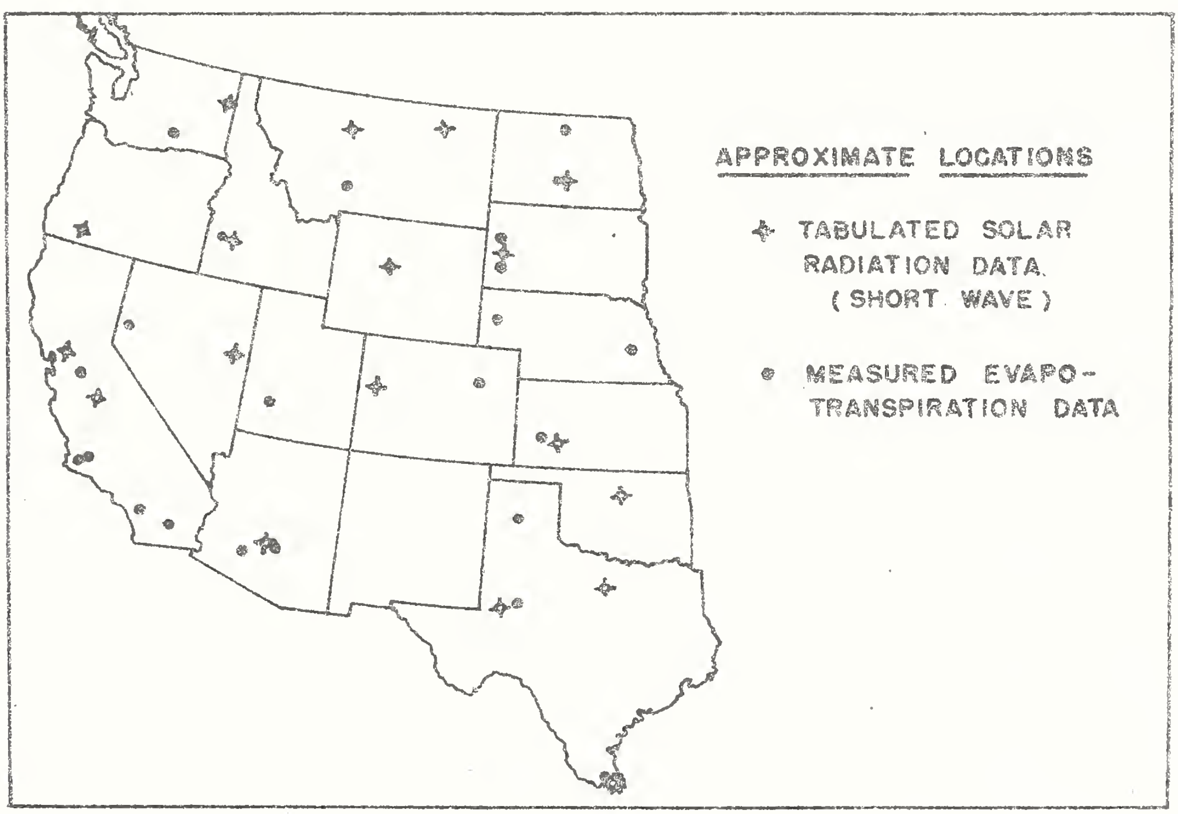

Fig. 8--Locations of tabulated solar radiation data (short wave) and measured evapotranspiration data in the 17 Western States.

TABLE 1.--Solar reflectance (r) and long-wave emmittance for various natural surfaces. (Summarized from (a) Brooks (1961) Table 57:7, p. 840, and (b) Budyko (1956) Table 4, p. 36.

Surface	Solar reflectance (0.3-2.5 microns)	Long-wave emmittance ϵ (2.5 microns up)	Source
Water, single surface reflectance, $i = 60^{\circ}$	0.06	0.95 - 0.96	(a)
Fresh dry snow	0.80 - 0.95		(b)
<u>Soil</u>			
Frozen soil		0.93 - 0.94	(a)
Dark soils	0.05 - 0.15		(b)
Moist grey soils	0.10 - 0.20		(b)
Dry, clay or grey soils	0.20 - 0.35		(b)
Dry, light sandy soils	0.25 - 0.45		(b)
Desert surface	0.25	0.90 (approx.)	(a)
Sand, dry	0.18		
Sand, wet	0.09	0.95 (approx.)	(a)
Moist ground, 70-90% bare	0.09 - 0.12		
Grass, high and dry	0.31 - 0.33	0.9 (approx.)	(a)
Common vegetables, fields and shrubs	0.24 - 0.28		
Wilted	0.30		
Alfalfa, dark green	0.03 (calc.)	(0.95)	(a)
Rye and wheat fields	0.10 - 0.25		(b)
Potato fields	0.15 - 0.25		(b)
Cotton fields	0.20 - 0.25		(b)
Meadows	0.15 - 0.25		(b)

where

ϵ = long wave emittance or emissivity

σ = Stefan-Boltzmann constant
(8.13×10^{-11} gm.cal/cm^2-$^{\circ}$K-min)

T = absolute temperature $^{\circ}$Kelvin
(273 + $^{\circ}$C)

The atmosphere also emits long wave radiation. The magnitude of thermal radiation from the atmosphere varies with temperature, water vapor content and cloud conditions. The source of the thermal energy emitted from the atmosphere is from some absorption of short wave radiation as previously indicated and absorption of thermal radiation from the ground and plants by water vapor primarily in the 4 to 8 micron range and wave lengths greater than 14 microns (Gates, 1959). Therefore, to obtain energy balance, incoming thermal radiation from the atmosphere and outgoing thermal radiation from the ground and plant surfaces must be considered. Generally ground and plant temperatures are higher than the effective sky temperature. Therefore, there is a net loss of thermal radiation from the ground and plant surfaces to the atmosphere (effective thermal radiation). An example of thermal radiation that is very common is the cooling of surfaces such as tops of autos on clear nights resulting in the collection of dew or frost (the effective sky temperature is less than dew point temperature near the ground). Considerably less loss of thermal radiation occurs with cloudy skies because clouds act almost as a black body for long wave radiation and since clouds are at low elevations, they are at higher temperatures than the effective sky temperature on clear nights.

There are equations for estimating atmospheric radiation (Bliss, 1961, and Brooks, 1952). Outgoing radiation can be computed using equation (2) if surface temperatures are known (Gates, 1961). Since the effective thermal radiation is dependent on air temperatures and vapor content, as well as surface temperatures, empirical equations have been developed for estimating effective thermal radiation. According to Gates (1959), Angstrom proposed such an equation in 1915, and Angstrom and Asklof developed a modification for this equation for cloudy conditions (Budyko, 1956). Berliand proposed the following equations having the form proposed by Brunt (from Budyko, 1956):

<u>For cloudless sky</u>

$$R'_{et} = \epsilon \sigma T^4 (0.39 - 0.058 \sqrt{e}) \quad \ldots \ldots \ldots \ldots (3)$$

where

R'_{et} = effective thermal radiation for a clear sky, gm.cal/cm^2-min.

ϵ = emissivity of the atmosphere
(0.72 - 0.90) See Bliss (1961)

T = air temperature, ^{o}K

e = partial pressure of water vapor, mm. Hg.

σ = Stefan-Boltzmann constant

For existing cloud cover

$$R_{et} = R'_{et} \left[1 - c\left(\frac{n}{10}\right)^{m} \right] \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

where

R_{et} = effective thermal radiation under existing conditions, gm.cal/cm^2-min.

n = cloud cover in tenths
clear, n = 0; cloudy, n = 10

m = 1.5 to 2.0

The above equations are similar to those used by Penman (1948) when computing net radiation except Penman used percent of possible sunshine in place of cloud cover. A more complete coverage of this subject can be found in meteorological texts and articles by Bliss (1961), Brooks (1952, 1955, 1961), Budyko (1956), and Gates (1959, 1961).

Dissipation of Energy in the Vegetated Zone

The main energy exchange that occurs in the vegetated zone is energy used for evapotranspiration (E_t). In addition, energy is used in heating the vegetation (s), the ground (G), the air (A), and in photosynthesis (P). These terms will be discussed further in the following sections.

Energy Balance Equations

An energy balance equation can be written using the various terms shown in figure 7. However, a reasonable assumption is required to simplify the equation; namely, that an adequate boundary of the same crop surrounds the area in question and that no temperature or vapor pressure gradient exists in a horizontal direction within the vegetated zone. Thus, it is assumed that the guard area surrounding the E_t site is sufficiently large to essentially eliminate so-called

"clothesline effect." The equation for energy balance for the vegetated zone then becomes:

$$R_s - rR_s + R_a - (R_g + R_p) - LE_t - G - A - P - s = 0 \quad . \; . \; (5)$$

where

R_s = solar and sky radiation flux (short wave)

r = albedo or reflectance

R_a = thermal radiation flux from the atmosphere

$(R_g + R_p)$ = thermal radiation flux from the ground and plants

L = latent heat of vaporization

E_t = rate of evapotranspiration

G = sensible heat flux to the ground (negative for flux from the ground)

A = sensible heat flux to the air (negative for flux from the air)

P = heat flux used in photosynthesis

s = heat flux stored in vegetated zone (negative for flux released from storage)

In this equation the first five terms represent net radiation (R_n)

$$R_s - rR_s + R_a - (R_g + R_p) = R_n \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (6)$$

For periods of 1 to 2 weeks we can further simplify this equation by neglecting several terms, s, P and G. The heat exchanged in the storage term (s) may be high for a few hours in early morning and evening (Tanner, 1960), but can be considered to be negligible for 1- to 2-week periods. The photosynthesis term P represents a maximum of about 5 percent of net radiation. Lemon (1960) has estimated P in a corn crop to be about 5 percent of R_n during midday and possibly larger on a daily basis. Budyko (1956) estimates P to be as high as 5 percent of R_s. The change in heat stored in the soil can be assumed to be negligible for 1- to 2-week periods.

The major terms remaining in the energy balance equation are:

$$R_s\ (1 - r) + (R_a - R_g - R_p) - LE_t - A \cong 0 \ldots\ldots\ldots (7)$$

where

$$(R_a - R_g - R_p) = \text{effective thermal radiation, } R_{et}$$

Equation (7) can be expressed in dimensionless terms by dividing by R_s, and after rearrangement becomes:

$$\frac{LE_t}{R_s} = 1 - r + \frac{(R_a - R_g - R_p)}{R_s} - \frac{A}{R_s} \ldots\ldots\ldots\ldots (8)$$

The ratio LE_t/R_s represents the combined effects of albedo or reflectance (r), effective thermal radiation (R_{et}) and heat flux to or from air by convection (A), and constitutes the major parameter in the solar radiation approach for estimating Et to be discussed later.

Since reflectance and thermal radiation for periods of about 1 week may be relatively constant except when a crop like alfalfa is cut, the main source of variability in the LE_t/R_s ratio arises from: (1) Limited soil moisture restricting E_t and causing greater heating of air (A becomes larger), and some increase in r and R_{et}, and (2) variations in A under adequate soil moisture conditions caused by a change from heating air (positive A) to cooling of air (negative A) by vertical turbulent heat exchange with r and R_{et} remaining relatively constant. Based on a preliminary analysis of the data to follow, the latter condition of turbulent transfer appears to be a major factor in any procedure for estimating E_t in semiarid and arid areas.

Turbulent transfer of heat may be expressed by the following differential equation (Budyko, 1956):

$$A = -\rho\, c_p\, k \frac{\partial T}{\partial Z} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where

ρ = air density

c_p = specific heat of air at constant pressure

k = coefficient of turbulent exchange

$\frac{\partial T}{\partial Z}$ = vertical gradient of temperature

If the air temperature decreases from the vegetated zone to the air just above, $\partial T/\partial Z$ will be negative and A will be positive.

However, if the air temperature above the vegetated zone is higher than the air temperature within the vegetated zone, $\partial T/\partial Z$ will be positive and A will become negative. This condition can be expected to occur frequently in irrigated areas. Tanner (1960) reports values of A for alfalfa-brome grass in Wisconsin of -2.36 mm/day or -0.093 inch/day. Lemon (1957) has reported similar advection of energy for cotton in Texas.

Computation or estimating numerical values of A are fairly easy for smooth surfaces using equations of the following form obtained by integrating equation (9) (Budyko, 1956):

$$A = \rho c_p D (T_s - T) \quad \ldots \quad (10)$$

where

D = diffusion coefficient

T_s = surface temperature

T = air temperature at some height

For water surfaces, the Bowen ratio can be used to estimate A.

For a growing crop, computing or estimating A become more difficult because a boundary is involved that is changing in roughness with time and is not stable because crops are flexed by wind. However, approximate equations have been developed. Such an equation for estimating positive A over grass is:

$$A = 0.61t (\Delta T_1)^{1.2} \quad \ldots \quad (11)$$

(cal/cm^2)

where

t = time of positive exchange, hours in 24

ΔT_1 = temperature difference between the soil surface under grass and air at 2m, ^oC

Negative exchange occurring at night when temperature inversion occurs is usually much smaller than under conditions of positive exchange during the day.

Because of the complexity of computing or estimating A for all types of crops and various stages of growth involved, the procedure proposed in this report uses the average value of r, R_{et}, and A as determined by evaluating measured E_t and R_s for the same period.

An example of advected energy, the results of which are visible, is the melting of snow by warm air. A common occurrence in the Great Plains States is to have a clear cold day with essentially little snow melting occurring, followed by another clear day but with warm southerly winds. Although some change in net radiation will occur, the main difference is the change in A from a positive value on the cold day to a negative value on the following warm day.

SOLAR RADIATION DATA

Solar radiation measurements made by the U. S. Weather Bureau were modified in 1952 as a result of improved procedures for cabibrating the Eppley pyrheliometer. Descriptions of the instruments and calibration procedures are described by MacDonald (1951) and MacDonald and Foster (1954). Weekly mean values of daily total solar and sky radiation (short wave) for a number of locations are available in a publication by Hand (1949). However, the year-to-year variability in solar radiation that occurs was not presented. Furthermore, if solar radiation is to be used for estimating E_t, it must be made readily available in convenient form for all areas in the West.

Solar radiation data from 1952 to date have been placed on punch cards at the National Weather Records Center at Asheville, North Carolina. Tabulations of data for 14 locations obtained from the U. S. Weather Bureau include weekly means of solar radiation, percent possible radiation, and mean and maximum temperatures. Photo copies of previous tabulations for six other locations also were obtained. Year-to-year standard deviations of mean weekly solar radiation were computed for 14 of 20 locations in the West. Measurements of solar radiation for all locations were then converted to inches per day evaporation equivalent using the latent heat of vaporization of water at 10^{o} C. (590 gm.cal/[redacted] gram) and are presented by weeks in table A-1 (Appendix)[1/]. In addition, total mean monthly solar radiation was computed from weekly means, converted to inches evaporation equivalent and are presented in table A-2 (Appendix) for all locations. Figure 8 illustrates the degree of coverage obtained in the 17 Western States. Several stations where only a few years of data were available are not shown in figure 8.

With only 7 to 9 years of solar radiation data available, smooth curves cannot be obtained by connecting the points of mean weekly values. Therefore, 4-week moving averages (table A-1) were computed and can be plotted for various locations as illustrated in figure 9. Year to year variation, $\pm$ one standard deviation is shown by the dashed lines. Solar radiation for a given week during a year can be expected to fall between the dashed lines in 2 out of 3 years.

Estimating solar radiation for specific periods

A number of equations have been developed for estimating solar radiation using either percent of possible sunshine or degree of

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1/ The 52nd week is an 8-day week, and the 26th week is an 8-day week in leap years.

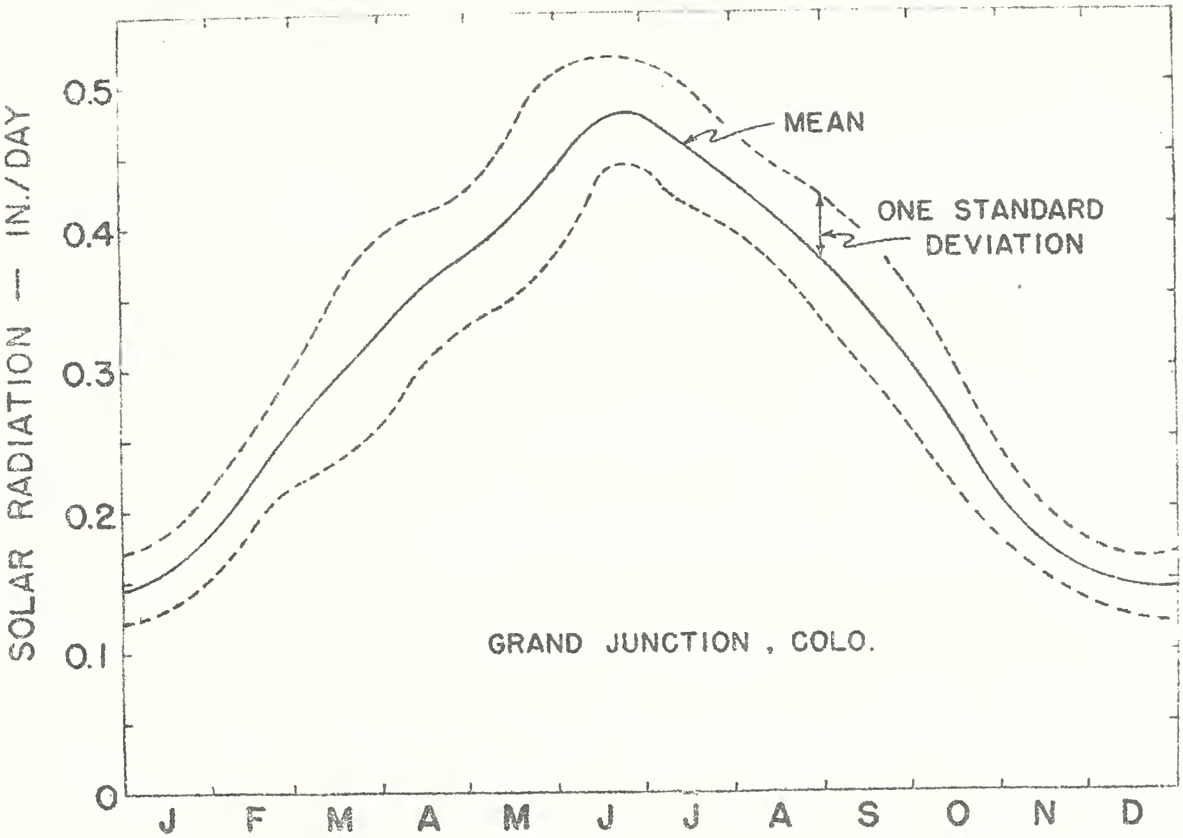


Fig. 9--Mean solar radiation expressed as in./day and year-to-year mean standard deviations at Grand Junction, Colorado (1952-60).

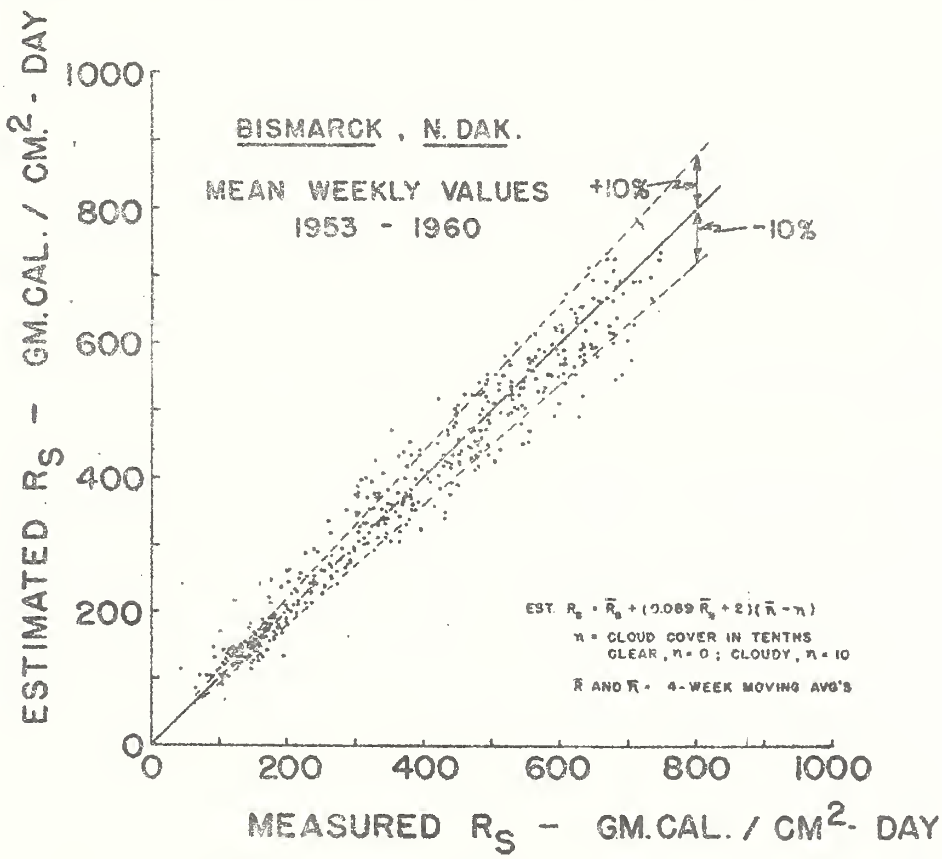


Fig. 10--Comparison of estimated mean weekly solar radiation (R_s) with measured mean weekly solar radiation at Bismarck, N. Dak. (1953-60). Estimates between dashed lines are within 10% of measured values.

cloud cover. Angstrom proposed the following equation in 1922. (from Budyko, 1956):

$$(Q + q) = (Q + q)_o \left[k + (1 - k) S \right] \quad \ldots\ldots\ldots\ldots (12)$$

where

$(Q + q)$ = total solar radiation under natural conditions

$(Q + q)_o$ = total solar radiation with clear skies

S = ratio of observed sunshine hours to possible sunshine hours

k = coefficient (0.235 at Stockholm)

This equation was modified by Savinov (from Budyko, 1956) to use cloud cover in place of sunshine resulting in the following equation used by Budyko in the publication "The Heat Balance of the Earth's Surface":

$$(Q + q) = (Q + q)_o \left[1 - (1 - k) \frac{n}{10} \right] \quad \ldots\ldots\ldots\ldots (13)$$

where

n = cloud cover in tenths (n varies from 0 to 10)

k = coefficient computed from data for 62 locations (see table 2, Budyko, 1956)

Kimball (1928) developed a similar equation for U. S. locations:

$$(Q + q) = (Q + q)_o \left[0.29 + 0.71 \left(1 - \frac{n}{10}\right) \right] \quad \ldots\ldots\ldots (14)$$

A curvilinear equation using cloud cover was developed by Black in 1956 (from Gates, 1959).

For this report mean solar radiation data (R_s) is included in tabular form for direct use, but a procedure was needed to estimate R_s for specific periods when E_t measurements were made. In some cases, solar radiation from nearby stations could be used directly. Rather than determine "clear day" solar radiation values in order to use one of the above equations, another equation was developed for adjusting mean measured solar radiation for specific periods if cloud cover was more or less than the average. The equation is

similar to those given above except mean solar radiation for natural conditions at a location is used instead of clear day values as a starting point as follows:

$$R_s = \bar{R}_s + K_{ss}\,(\bar{n} - n) \quad \ldots\ldots\ldots\ldots \quad (15)$$

where

R_s = total solar and sky radiation for a specific period

$\bar{R}_s$ = 4-week moving average of R_s for the period

K_{ss} = correction coefficient

n = mean cloud cover, sunrise to sunset in tenths (clear, $n = 0$; cloudy, $n = 10$)

$\bar{n}$ = 4-week moving average of, n, for the specific period

Thus if actual cloudiness, n, is equal to the 4-week mean cloudiness, $\bar{n}$, no correction is needed. Values of K_{ss} for 19 locations were determined by plotting mean weekly values of solar radiation versus mean cloud cover for each location (approximately 450 points for each location). The slope ($-K_{ss}$) of a straight line fitted to these points by eye for each week was then determined (approximately 1000 values). The correction coefficient could then be expressed as a linear function of the 4-week moving average of solar radiation:

$$K_{ss} = b\,\bar{R}_s + a \quad \ldots\ldots\ldots\ldots \quad (16)$$

Values of a and b that reflect the type of cloud cover occurring at various locations are presented in table 2. A curve of K_{ss} versus R_s can be plotted for the location that is being used for convenience in determining K_{ss}.

Four-week moving averages of cloud cover are also presented in table A-1. Cloud cover is being recorded in tenths (0 to 10) by the U. S. Weather Bureau for the periods sunrise to sunset and midnight to midnight. Equation 15 requires the use of cloud cover from sunrise to sunset expressed in tenths. Records of cloud cover based on hourly averages are available from 1950 to date. Prior to 1950 cloud cover was based on only two to three observations per day. The number of clear, partly cloudy and cloudy days are given in U. S. Weather Bureau Technical Paper No. 12, "Sunshine and Cloudiness at Selected Stations in the United States, Alaska, Hawaii and Puerto Rico". However, the 1950-1960 averages differ slightly from those obtained by computing average cloudiness from clear, partly cloudy and cloudy days and average cloud cover in tenths based on 2-3 daily observations. Therefore when using a value for $\bar{n}$, the same number of daily observations upon which n is based should be used or adjusted accordingly.

TABLE 2.--Values of constants a and b for use in equation 16 ($K_{ss} = b\,\overline{R}_s + a$)

Location		Equation for K_{ss}
Phoenix, Arizona		$0.027\,\overline{R}_s + 7$
Davis, California		$0.010\,\overline{R}_s + 17$
Fresno, California		$0.060\,\overline{R}_s + 8$
Grand Junction, Colorado		$0.066\,\overline{R}_s + 2$
Boise, Idaho	January-June	$0.022\,\overline{R}_s + 19$
	July-December	$0.024\,\overline{R}_s + 13$
Dodge City, Kansas		$0.101\,\overline{R}_s - 4$
Glasgow, Montana		$0.072\,\overline{R}_s - 4$
Great Falls, Montana		1/
Ely, Nevada		$0.082\,\overline{R}_s -6$
Bismarck, North Dakota		$0.089\,\overline{R}_s + 3$
Stillwater, Oklahoma		1/
Astoria, Oregon	January-June	$0.130\,\overline{R}_s + 9$
	July-December	$0.068\,\overline{R}_s + 11$
Medford, Oregon		1/
Rapid City, South Dakota		$0.100\,\overline{R}_s - 6$
Brownsville, Texas		$0.078\,\overline{R}_s + 3$
Fort Worth, Texas	January-June	$0.089\,\overline{R}_s + 7$
	July-December	$0.046\,\overline{R}_s + 16$
Midland, Texas		$0.076\,\overline{R}_s - 6$
Spokane, Washington		$0.036\,\overline{R}_s + 21$
Lander, Wyoming		$0.081\,\overline{R}_s - 6$

1/ Computations not completed for this location.

Equation (15) can also be used to adjust mean solar radiation from any of the 20 locations to other nearby locations at about the same latitude and elevation. Between any two locations at different latitudes for which data are available, linear interpolation can be used if cloud cover is similar. If cloud cover for the location is materially different from both adjacent locations then solar radiation for each adjacent location should be adjusted using the mean cloud cover of the specific location before a linear interpolation is made. If the specific location for which estimates are needed has a considerably different elevation other adjustments are needed. As elevation increases, R_s on clear days also increases because of less total water vapor that must be penetrated. Meteorological texts provide correction procedures for elevation.

Reliability of estimating solar radiation

In order to evaluate the suitability of equation (15) for estimating solar radiation, three locations were selected using mean cloud cover for weeks that solar radiation was measured. Figures 10 and 11 illustrate the differences between estimated and measured mean weekly solar radiation for Bismarck and Phoenix. The average error for Bismarck was 8.8 percent and for Phoenix 5.1 percent. Greater variability in cloud thickness and density probably accounts for the larger errors at Bismarck. Similar values were obtained for Grand Junction where the average error was 8.4 percent.

For longer periods, such as a month, greater accuracy is obtained. A comparison of estimated versus measured mean monthly solar radiation for Bismarck, Grand Junction and Phoenix, for April and September is presented in figure 12. These values were obtained by estimating R_s for individual weeks and averaging 4 weeks to obtain monthly means. All but 2 of the 44 estimates are within 5 percent of the measured values.

As previously indicated, solar radiation is more closely associated with E_t rates than mean temperature. Therefore with the indicated accuracy of adjusting solar radiation on the basis of cloud cover and with the availability of data, solar radiation becomes a more logical major parameter to use for estimating E_t than mean temperature.

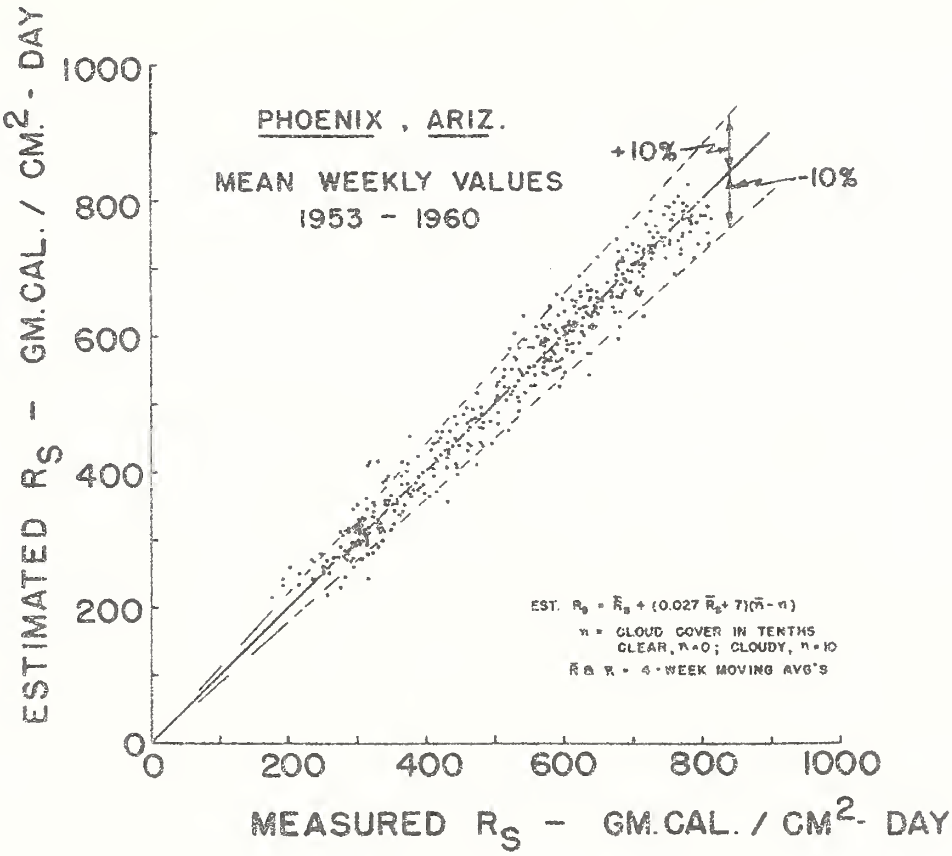


Fig. 11--Comparison of estimated mean weekly solar radiation (R_s) with measured mean weekly solar radiation at Phoenix, Arizona (1953-60). Estimates between dashed lines are within 10% of measured values.

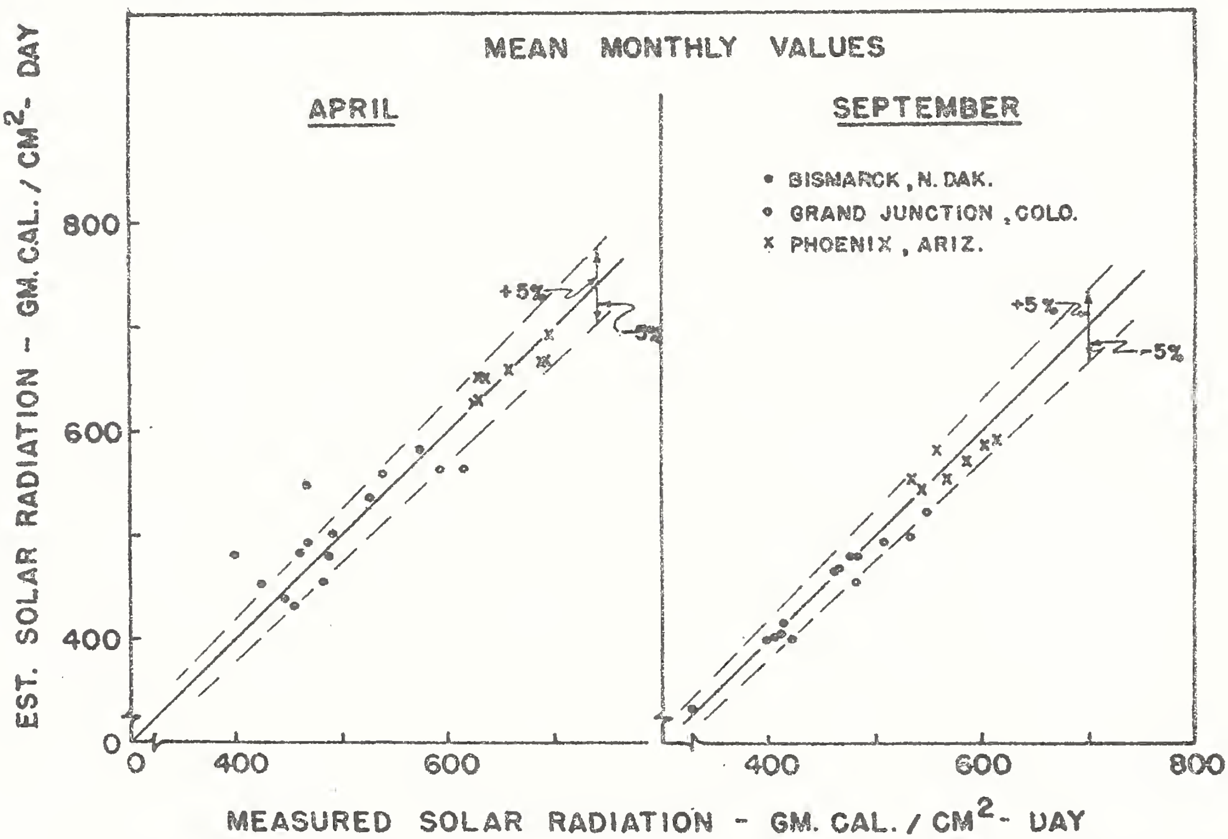


Fig. 12--Comparison of estimated mean monthly solar radiation with measured mean monthly solar radiation in April and September at 3 locations (1953-60).

THEORETICAL (LE_t/R_s) RATIOS

The magnitude of (LE_t/R_s) ratios for specific stages of crop growth can be estimated using equation (8). For example, consider grain sorghum grown as a row crop in the Texas High Plains area on a silty clay loam soil. Three stages of growth will be considered: several weeks after planting, midseason and near maturity. Equation (4) is used to estimate effective thermal radiation. Equation (11) is used with soil surface and air temperatures reported by Army and Hudspeth (1960) to estimate the value of A several weeks after planting. The value of A for midseason and near harvest will be assumed to be zero. Reflectance values and R_s are also estimated. (Equation 8 is repeated for convenience.)

$$\frac{LE_t}{R_s} = 1 - r + \frac{R_{et}}{R_s} - \frac{A}{R_s} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (8)$$

The results obtained from these calculations are as follows:

State of growth	R_s gm.cal/cm^2-day	r	Ret gm.cal/cm^2-day	A gm.cal/cm^2-day	LE_t/R_s
Several weeks after planting	660	0.25	148	50	0.45
Midseason	610	.15	144	0	.61
Near maturity	405	.20	155	0	.42

The above data indicate that several weeks after planting, a LE_t/R_s ratio of about 0.45 can be expected. Then if advected energy is zero (all net radiation used for E_t), a ratio of about 0.61 can be expected with maximum crop cover. As the crop approaches maturity the ratio can be expected to decrease to about 0.42.

If advected energy from surrounding drier areas was being transferred to the sorghum during midseason at an average rate of 0.05 inch per day (A = 75 gm.cal/cm^2-day), the (LE_t/R_s) ratio during midseason would be 0.72, and the value of E_t would be 0.317 in./day. These estimates can be substantiated by actual data on grain sorghum obtained at Bushland, Texas (unpublished data by Army, Jensen, Bond and Sletten). During the period August 4 to 18, 1959, the following measurements were obtained using an Agmet net radiometer and soil sampling procedures on plots receiving adequate irrigation at midseason.

Measured R_n = 0.230 in./day

Measured E_t = 0.287 in./day

Estimated A = -0.057 in./day ($R_n - E_t = A$)

Using equations 4, 15 and 7, and table 1 for the same period the following figures are obtained:

$$\text{Estimated } R_s = 0.392 \text{ in./day}$$

$$\text{Estimated } R_{et} = 0.106 \text{ in./day}$$

$$\text{Estimated } r = 0.15$$

$$R_n = 0.227 \text{ in./day}$$

$$\text{Estimated } A = -0.060 \text{ in./day}$$

Data obtained by Pruitt and Angus (1961) using a 20-foot diameter weighing lysimeter planted with rye grass and located in a field of the same grass has produced similar results. The following data were obtained from mean curves for January - May 1960 and July - December 1959. Data obtained on dry, strong-wind days were excluded from the mean curves that are used. The ratio E_t/R_s is identical to LE_t/R_s if E_t and R_s are expressed in the same units.

January - May 1960			July - December 1959		
E_t mm/day	R_s mm/day	E_t/R_s	E_t mm/day	R_s mm/day	E_t/R_s
0.66	3	0.22	0.79	3	0.26
2.18	6	.36	2.92	6	.49
3.70	9	.41	5.06	9	.56
5.23	12	.44	7.19	12	.60

At the highest average E_t rate, 7.19 mm/day or 0.283 inch/day, the LE_t/R_s ratio was 0.60. On windy days values of LE_t/R_s greater than 1.00 were measured.

In summary, theoretical and measured values of the LE_t/R_s ratio can be expected to be from 0.55 to 0.60 during midseason with complete crop cover, adequate soil moisture, and no advected energy. If advection occurs, values of the LE_t/R_s ratio may reach 0.8 to 1.0 depending on the amount of advected energy that is received in the irrigated field from surrounding drier areas.

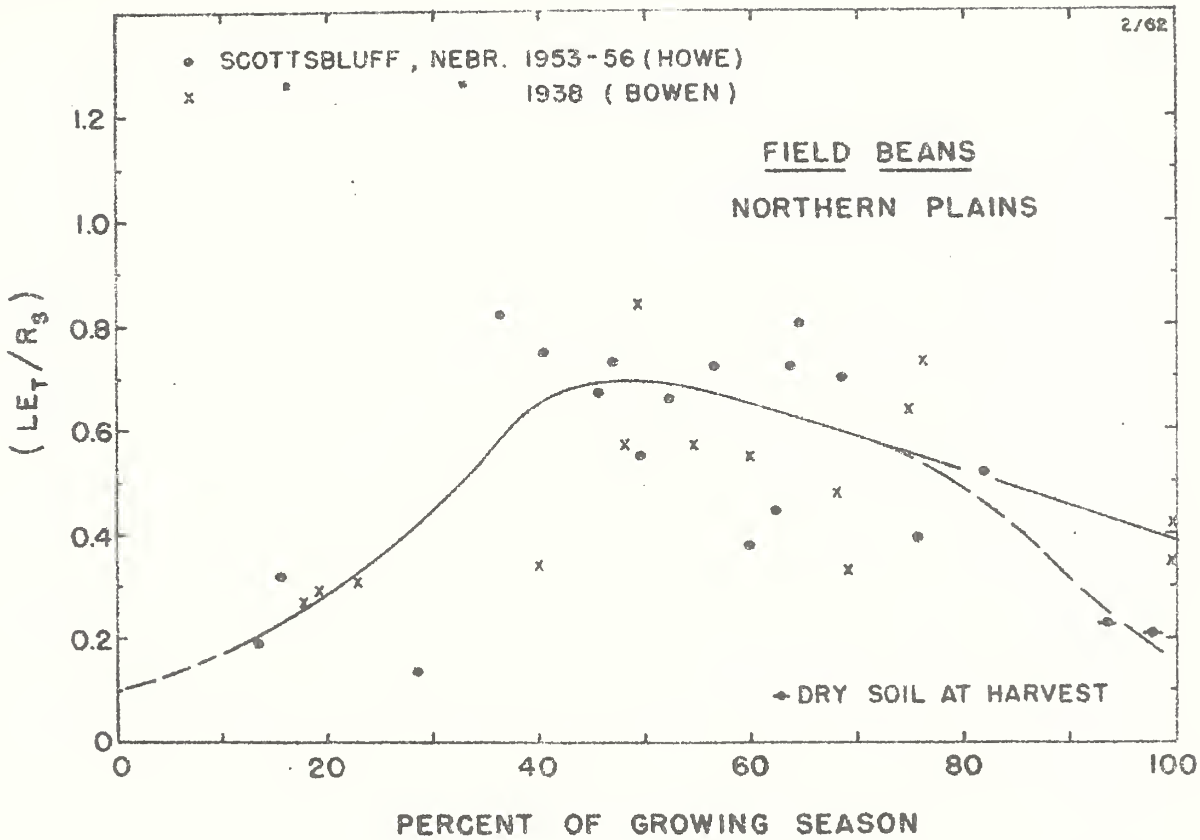
MEASURED LE_t/R_s RATIOS

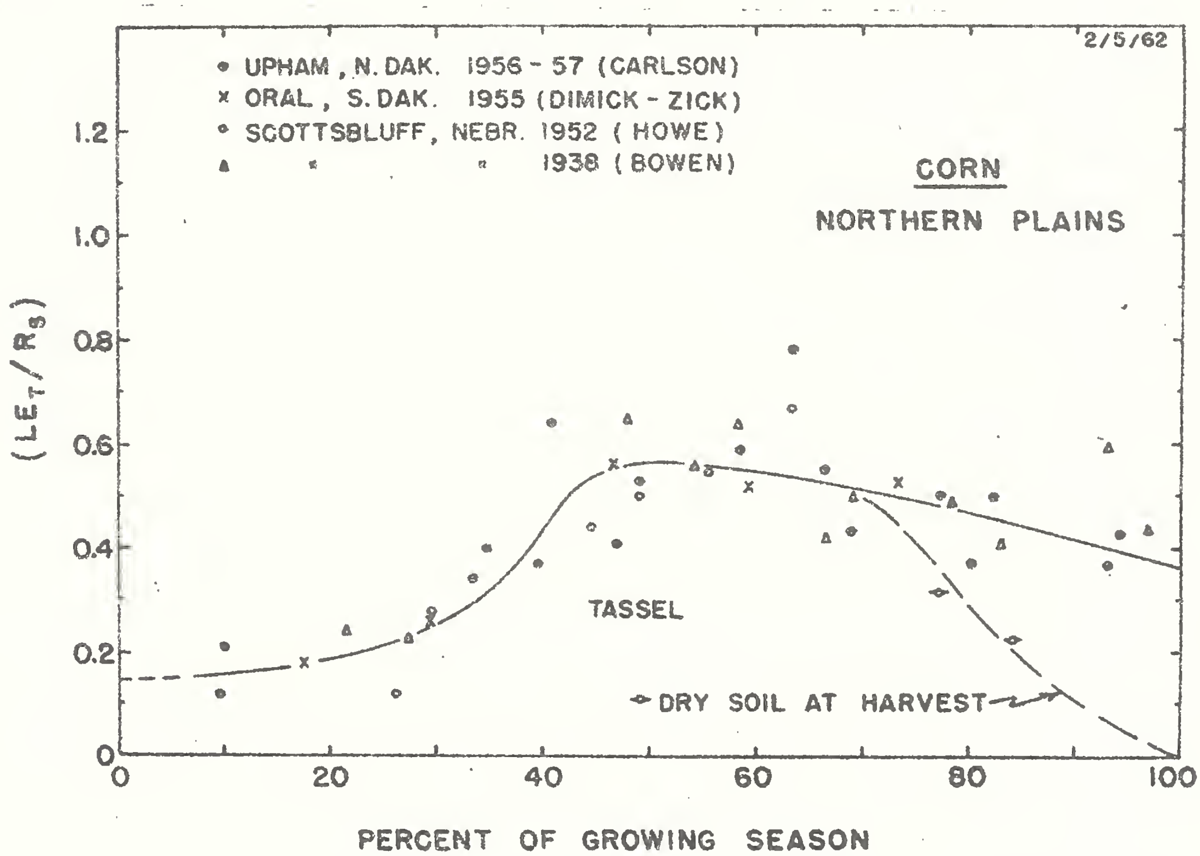
Measured LE_t/R_s ratios for field beans, corn, grain sorghum, sugar beets, alfalfa, and cotton are plotted against percent of crop growing season in figures 13-21, inclusive. The ratios for field beans, corn, grain sorghum, and cotton increase rapidly as vegetative cover is developing. Ratios for sugar beets increase less rapidly. The maximum ratio where E_t approaches potential E_t occurs near midseason. From midseason to maturity, the ratio generally decreases due to changes in plant characteristics as expected with the exceptions of sugar beets and alfalfa. A crop of sugar beets (figures 17 and 18) has a dense crop cover until harvest or killing frost and would be expected to transpire at about the same rate once cover had been established.

In contrast, (figure 19) alfalfa is a perennial and develops an early effective cover as soon as temperatures are favorable. If cuttings are not considered, the LE_t/R_s ratio is essentially constant throughout the growing season. However, the ratio drops markedly when a cutting occurs within a measured period. Bahrani and Taylor (1961) found that following the cutting of alfalfa, net radiation and E_t decreased and surface soil temperature increased. Net radiation is affected by reflectance and effective thermal radiation. From table 1, reflectance would increase when the alfalfa was cut from about 0.03 to 0.10 with moist soil at the surface and possibly higher as the soil surface dried. The higher surface temperature increases effective outgoing thermal radiation since it is a function of temperature of the surface to the fourth power. Hence, the decreased LE_t/R_s ratio observed when cutting alfalfa at Prosser, Washington, may be due largely to changes in net radiation plus some changes in the transpiration capacity of the crop. Therefore, periods when a crop such as alfalfa is cut must be considered in estimating E_t rates.

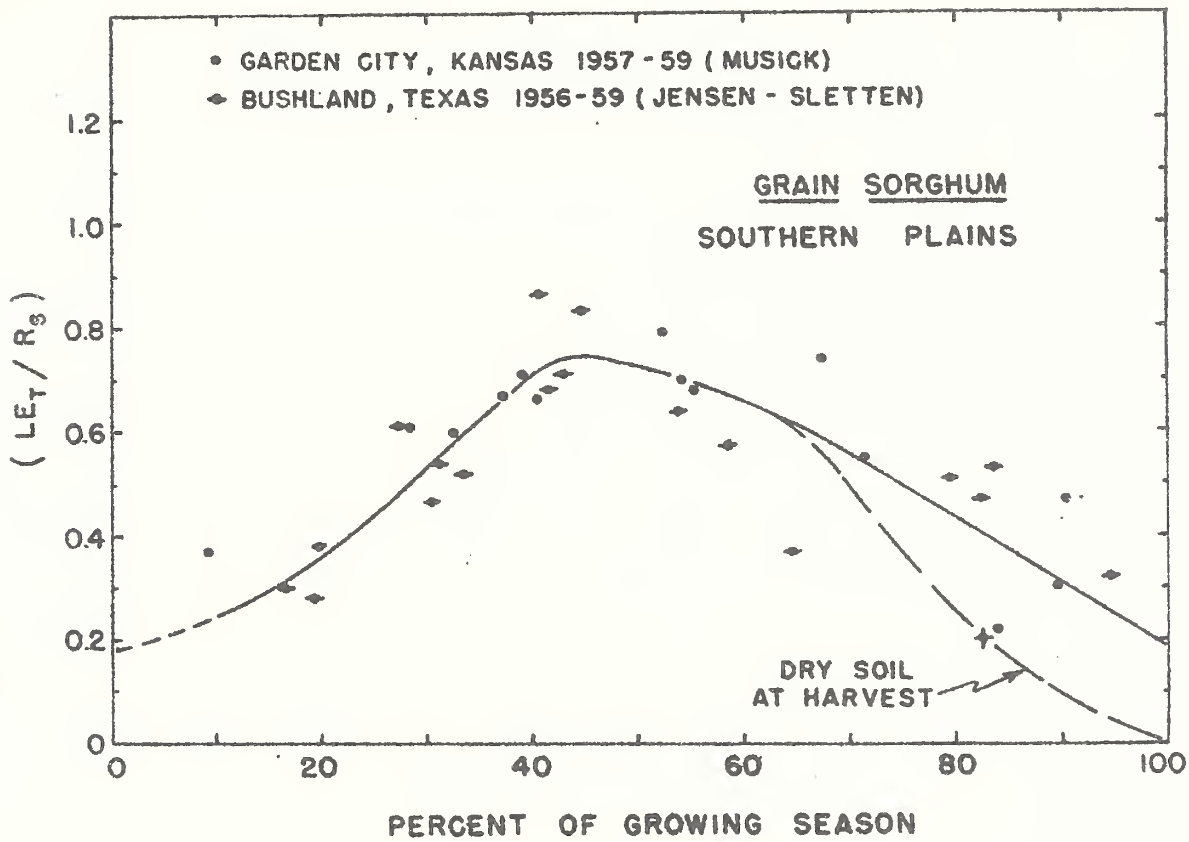
The difference in planting date and growing conditions for grain sorghum are contrasted in figures 15 and 16. Note that near potential E_t is approached at approximately 40 percent of growing season at Garden City, Kansas, and Bushland, Texas, whereas the same point is reached at 25 percent of the growing season at Mesa, Arizona. At the latter location, grain sorghum is planted about July 1 when temperatures are higher and growing conditions are favorable for more rapid establishment of a dense crop cover. Planting dates in Texas high plains and western Kansas are about June 10-15.

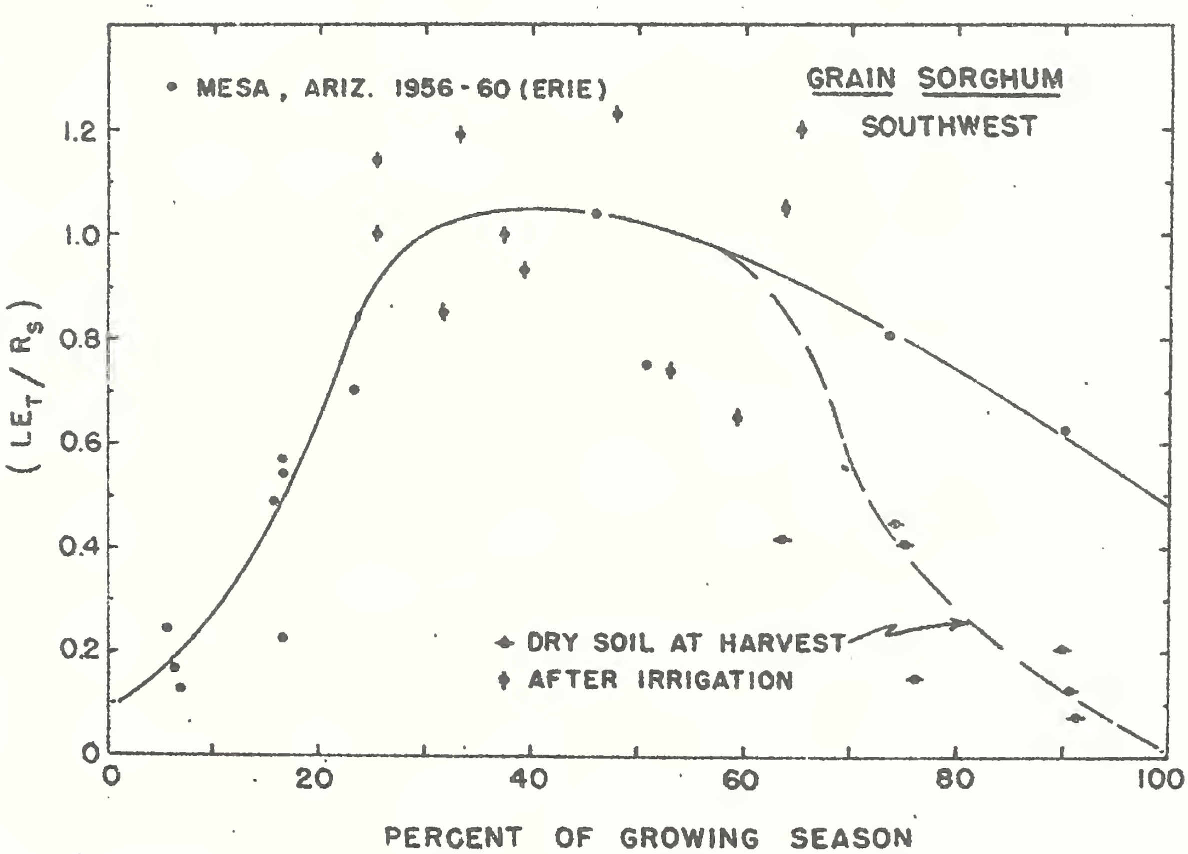
Plotted LE_t/R_s ratios for sugar beets presented in figures 17 and 18 show more scatter than do those of any other crops analyzed thus far. However, this is partly a result of purposely including data from sampling periods when it appeared that irrigations were not as frequent as desired. As a result, many low E_t rates were measured just prior to irrigations. The scatter was equally as



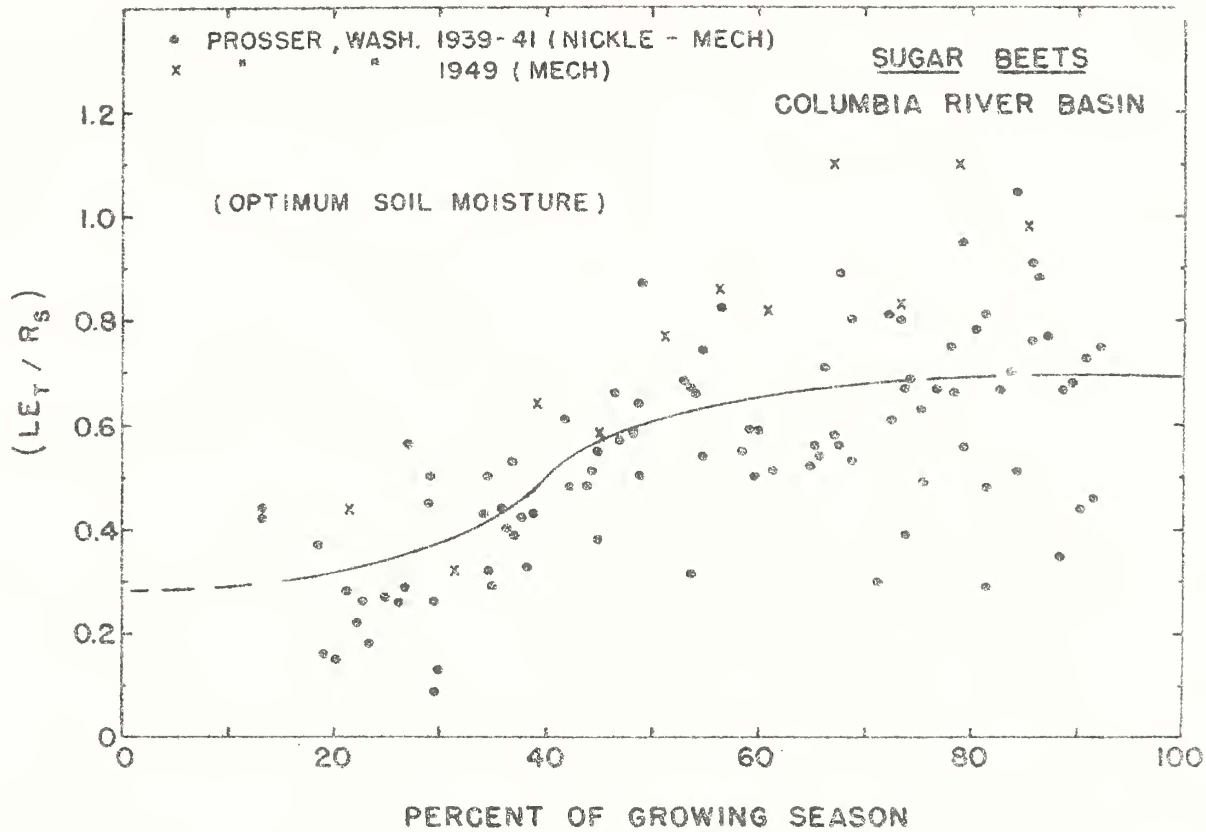


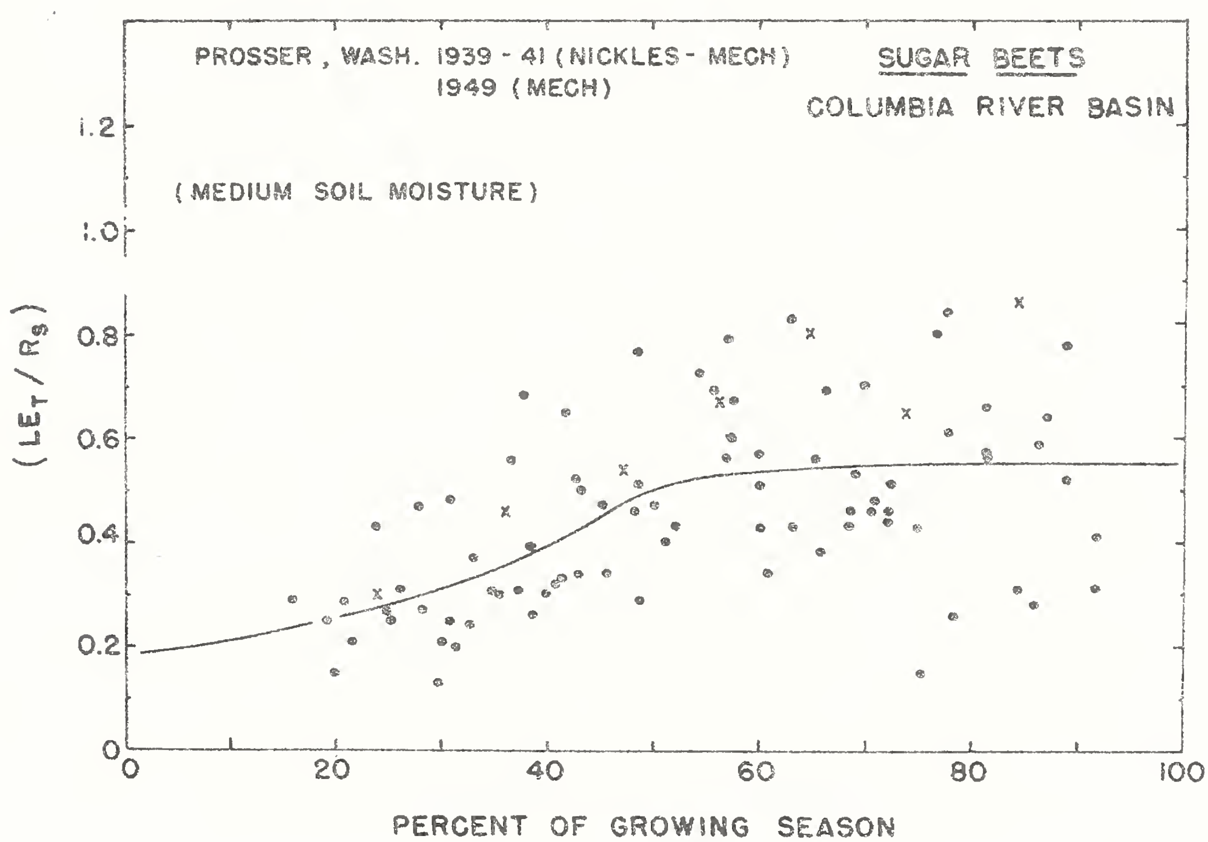
Figs. 13 and 14--Variation in the E_t-solar radiation ratio (LE_t/R_s) for field beans (top) and for corn (bottom) in relation to stage of growth expressed as per cent of growing season at 3 locations in the Northern Plains. Broken line denotes LE_t/R_s ratio where avail. soil moisture nearly depleted at crop maturity.



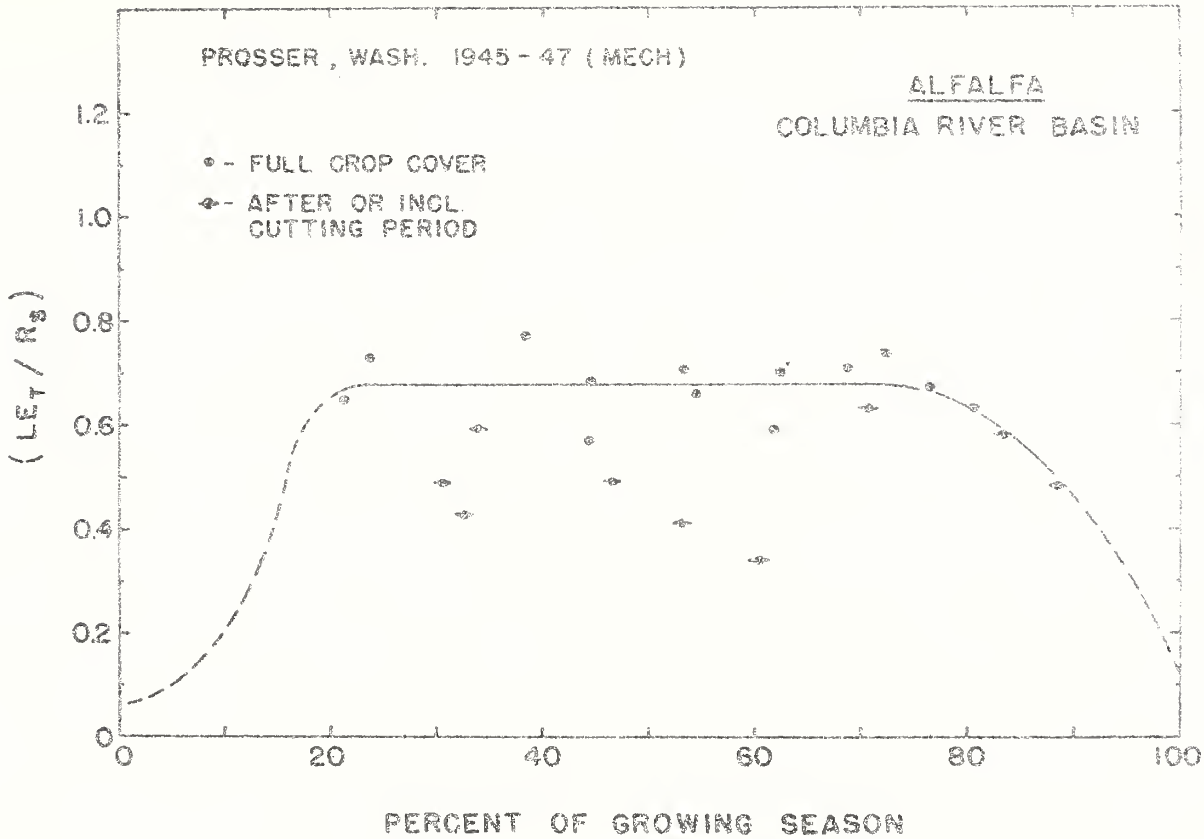


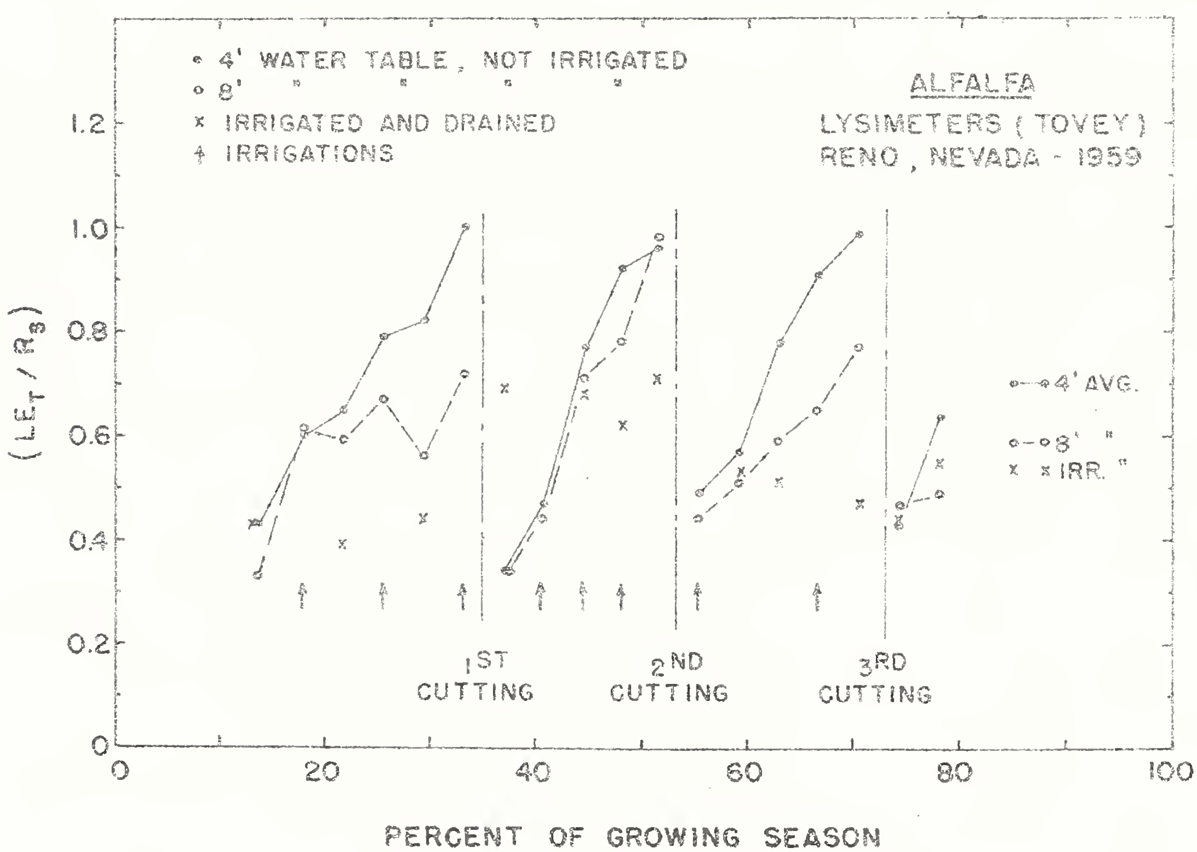
Figs. 15 and 16--Variation in the E_t-solar radiation ratio (LE_t/R_s) for grain sorghum in relation to stage of plant growth expressed as percent of growing season in Southern Plains (top) and Southwest (bottom). Broken line denotes LE_t/R_s ratio where available soil moisture was nearly depleted at crop maturity.





Figs. 17 and 18--Variation in the Et-solar radiation ratio (LE_t/R_s) for sugar beets grown under "optimum" (top) and "medium" (bottom) soil moisture conditions in relation to stage of plant development expressed as percent of growing season at Prosser, Washington (1939-41 and 1949).





Figs. 19 and 20--Variation in the E_t-solar radiation ratio (LE_t/R_s) for alfalfa in relation to percent of growing season at Prosser, Wash. (top). Alfalfa grown in lysimeters and cut 3 times with water table at 4 and 8 feet and with no water table, Reno, Nevada (bottom).

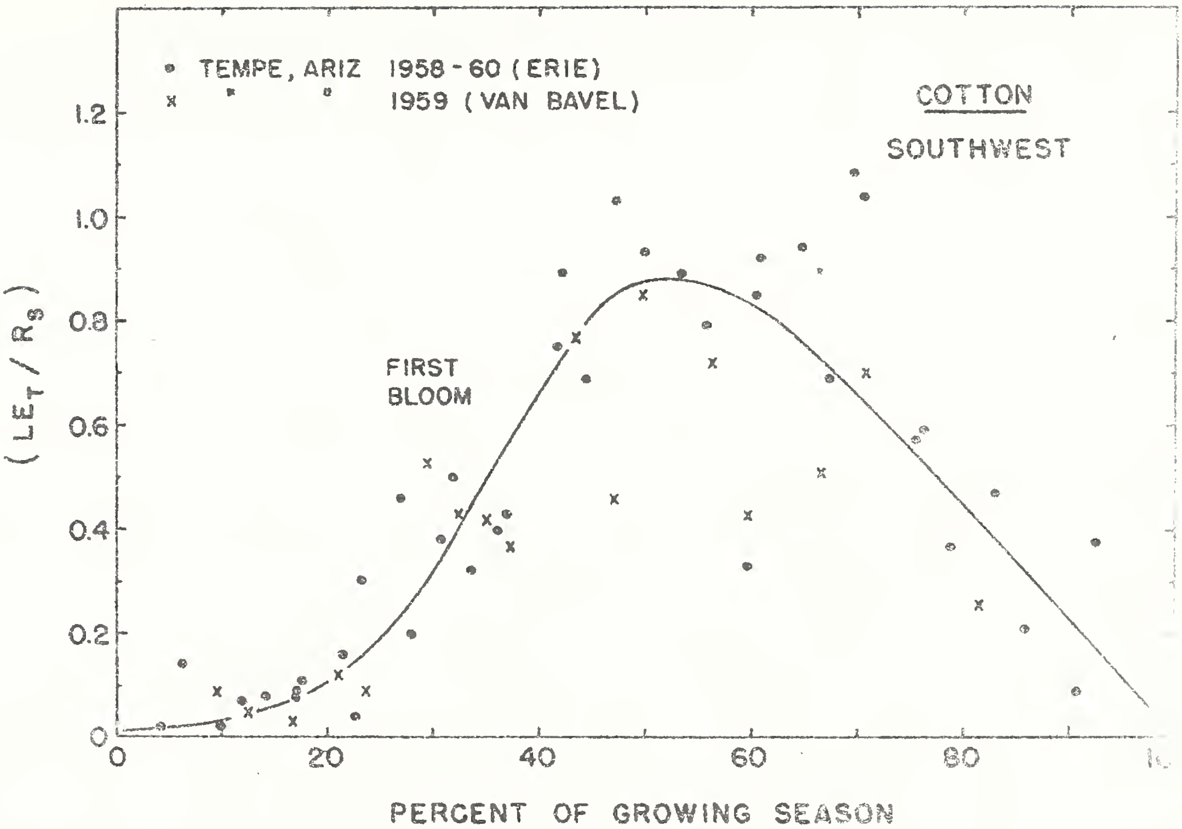


Fig. 21--Variation in the E_t-solar radiation ratio (LE_t/R_s) for cotton in rel... to stage of growth expressed as % of growing season, Tempe, Ariz.(...

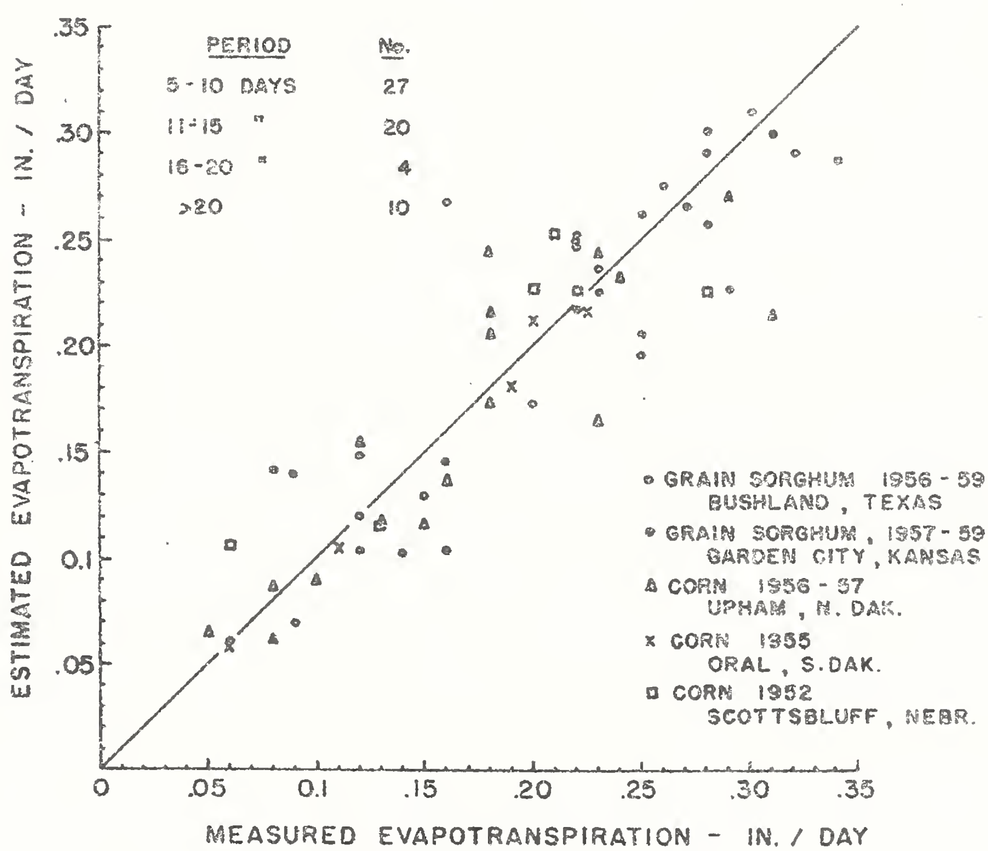


Fig. 22--Comparison of estimated E_t rates (in./day) with measured E_t rates duri... periods ranging from 5 to 20 days for grain sorghum and corn in Gre...

great for what was called the "optimum" and "medium" moisture treatments indicating that deep percolation losses were not necessarily a major factor in the higher ratios obtained. Further evaluation of E_t data by Nickle will be needed as time between irrigations may have been excessive. Lemon (1957) has shown that increased soil moisture tension can decrease transpiration rates materially. The mean curve, however, should represent average conditions between irrigations during the growing season. Several sampling periods usually occurred between irrigations and if these were averaged to give only one value between irrigations, there would be much less scatter of points.

The measured values for alfalfa and most of the other crops observed to date are generally more consistent during the first 40 to 50 percent of the growing season. Estimates of E_t rates using mean curves likewise would be more accurate during this period which corresponds to the time when most of the season's irrigations are applied. For this reason, a "bookkeeping system" to schedule irrigations based on the mean LE_t/R_s ratio and solar radiation received can be reasonably successful. Scatter of data near the end of the season is not as critical. An example of the effect of the scatter on estimated E_t rates near the end of the season is needed to illustrate this point. Consider the "optimum" soil moisture data in figure 17. The mean LE_t/R_s ratio is 0.69 at 80 percent of the growing season. Most of the points fall between ratios of 0.50 and 0.90. The mean solar radiation at this time of the year at Prosser is about 0.27 in./day. Therefore, the average estimated E_t rate would be 0.19 in./day and the E_t rate for ratios of 0.50 and 0.90 would be equivalent to 0.14 and 0.24 in./day. Thus, even with the large scatter late in the season but using the mean value of LE_t/R_s for estimating purposes would give estimates that were within 0.05 in./day from the observed values. Another reason for more scatter in the Prosser data is that most of the data were from sampling periods of 4 to 8 days and during the years 1939-1941, moisture levels probably were not maintained as rigorously as during the studies made on alfalfa in 1945-1947.

On the basis of preliminary observations for development of a reasonably accurate E_t estimating procedure, recognition must be given to and correlations developed with the same crop grown within a geographic area of similar climate, i.e. the northern Plains, the southern Plains, the Southwest, etc. Grain sorghum grown in the Southwest and southern Plains (figures 15 and 16) illustrates the need for developing ratios for each crop on a regional basis. As pointed out previously, planting dates, growing conditions, etc. can markedly affect the growth characteristics of a crop and, correspondingly, the LE_t/R_s ratio.

One observation common to all LE_t/R_s curves presented is the magnitude of ratios that occur near midseason when Et should approach potential E_t. As previously discussed, a ratio greater

than about 0.6 indicates that additional or advected heat is available to evaporate water. Whether LE_t/R_s values above 0.6 are the result of E_t measurements taken in small plots, as was frequently the case, is a matter of conjecture. Certainly the possibility of horizontal divergence of heat or "clothes line" effect cannot be overlooked for some data from small plots. It is of interest, however, that minimum advection appears to occur for corn in the more humid northern Plains (figure 14) in contrast to grain sorghum and cotton in the arid Southwest (figure 16).

The influence of advected heat is also apparent in the case of alfalfa grown in lysimeters at Reno, Nevada (figure 20). Note that LE_t/R_s ratios increase almost linearly with alfalfa growth with water table at 4 and 8 feet. In contrast, corresponding ratios for the irrigated and drained lysimeters are generally lower except immediately following the first cutting. An irrigation was applied just prior to the first cutting which probably resulted in cooler soil surface temperatures and higher net radiation. Advected energy could also be greater under these conditions. The combined effects of greater net radiation, higher advected energy and more surface moisture would result in a higher ratio for the irrigated lysimeters after cutting than the non-irrigated lysimeters. E_t data from irrigated and drained lysimeters during the week of irrigation were not used. These will be included later for further analysis.

The average yields and LE_t/R_s ratios for the three treatments (average of 3 soils and 3 replications) were as follows:

	Yield	LE_t/R_s
4-foot water table, not irrigated	8.69 tons/acre	0.70
8-foot water table, not irrigated	8.21 tons/acre	0.59
Irrigated and drained	8.09 tons/acre	0.54

The weighted average LE_t/R_s ratio for alfalfa at Prosser, Washington, covering a period from 18 to 94 percent of the growing season was 0.59 including the cutting periods. The possibility of the pronounced effect of cutting on the LE_t/R_s ratio where a water table is ~~was~~ involved ~~occurring~~ under field conditions is a matter of conjecture at this time.

ESTIMATING EVAPOTRANSPIRATION FROM SOLAR RADIATION

Estimating Evapotranspiration Rates

Solar radiation can be used to estimate E_t rates for various stages of growth. Only two simple steps are involved: (1) determine the solar radiation rate, R_s, in inches per day at the time of year that corresponds to the specific stage of growth for which an estimate is needed, and (2) multiply R_s by the mean measured (LE_t/R_s) ratio.

$$\text{Estimated } E_t = \left(\frac{LE_t}{R_s}\right)_m \times R_s \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

where

$\left(\frac{LE_t}{R_s}\right)_m$ = the mean measured ratio as shown by the curves in figures 13-21

R_s = solar radiation from table A-1, inches/day

Example No. 1: Determine average maximum E_t for irrigated grain sorghum near Dodge City, Kansas. The following crop data are typical for the area:

Planting date - June 10

Harvest date - October 25

Growing season - 137 days

Average maximum $(LE_t/R_s)_m$ ratio = 0.74 (from figure 15) (Boot to heading stage)

This average ratio occurs during 40 to 50 percent of the growing season or August 4 to 17 (31st to 33rd week)

From table A-1 maximum $\overline{R_s} \cong 0.425$ inches/day during this period

$$\text{Estimated } E_t = \left(\frac{LE_t}{R_s}\right)_m \times R_s = 0.74 \times 0.425 = \underline{\underline{0.31 \text{ inches/day}}}$$

If additional information on year-to-year variability of E_t is desired, this can also be estimated. First assume that average advected energy will occur. The mean standard deviation of R_s for the same period above is 0.036 inches/day. Therefore, 2 out of 3 years' R_s can be expected to vary from 0.389 to 0.461 inches/day (0.425 ± 0.036). Therefore, E_t can be expected to vary from about 0.29 to 0.34 inches/day.

Actual solar radiation is available from a number of U.S. Weather Bureau locations. If estimates are needed for specific periods of time in a given year, use actual solar radiation if it is available nearby or estimate the solar radiation for the specific period using equation 15.

If the average rate of E_t is needed for a specific period 5 to 15 day period, the midpoint of this period is desirable. The midpoint of the period expressed as a percentage of the crop growing season can also be calculated using the following equation and dates, d, expressed as 1 to 365 during the year.

$$\text{Midpoint in percent} = \frac{(d_1 + d_2 - 2d_1)}{2\ D_s}\ 100 \quad \ldots\ldots\ldots \quad (18)$$

where

d_1 = date at the beginning of the period

d_2 = date at the end of the period

D_s = days in the crop growing season (harvest date - planting date for annual crops)

An example of how this equation is used is as follows:

Example No. 2: find ~~the~~ The midpoint of an 8-day period, August 1 to 9 expressed as a percentage of the crop growing season used in example No. 1.

August 1 = 213th day of the year

August 9 = 221st day of the year

Planting date, June 10 = 161st day of the year

$$\text{Midpoint} = \left[\frac{213 + 221 - 2(161)}{2(137)}\right] 100$$

$$= \underline{\underline{40.9 \text{ percent}}}.$$

Estimating Total Evapotranspiration for a Specific Period

Solar radiation can also be used to estimate total evapotranspiration for a given period using the following equation:

$$\text{Total } E_t = \frac{\int_{S_1}^{S_2} \left(\frac{LE_t}{R_s}\right)_m R_s dS}{S_2 - S_1} \times D \quad \ldots\ldots\ldots\ldots\ldots \quad (19)$$

where

$\left(\frac{LE_t}{R_s}\right)_m$ and R_s are as defined for equation (17)

dS = increment of the growing season

S_1 and S_2 = percent of growing at the beginning and end of the specific period, calculated using equation 18.

D = days in the period

Example No. 3: How much water will irrigated grain sorghum use during the month of August under average climatic conditions using the same crop conditions as used in example no. 1?

$$\text{July 31} = \left(\frac{20 + 31}{137}\right) 100 = 37 \text{ percent of the growing season}$$

$$\text{August 31} = \left(\frac{20 + 31 + 31}{137}\right) 100 = 60 \text{ percent of the growing season}$$

The period in question represents 23 percent of the growing season, (60 - 37 = 23). Divide the period into several increments such as 8, 8, and 7 percent whose midpoints are at:

37 + 4 = 41 percent (August 5)
41 + 8 = 49 percent (August 16)
49 + 7.5 = 56.6 percent (August 26)

For the 3 increments of the period the following data are obtained from figure 15 and table A-1, Dodge City, Kansas:

Increment	Midpoint (S) %	$\left(\frac{LE_t}{R_s}\right)_m$	$\bar{R}_s$ in./day
1	41	0.72	0.42
2	49	.73	.40
3	56.5	.69	.38

Estimated total E_t for August

$$= \frac{[(0.72)(0.42)(8) + (0.73)(0.40)(8) + (0.69)(0.38)(7)]}{60 - 37} \times 31$$

$$= \frac{(2.42 + 2.34 + 1.84)}{23} \times 31 = 0.287 \times 31 = \underline{\underline{8.9 \text{ inches}}}$$

Estimated total E_t for August = $\underline{\underline{8.9 \text{ inches}}}$

If quick estimates are needed for periods of a month, total solar radiation for the month obtained from table A-2 can be used providing the $(LE_t/R_s)_m$ ratio is relatively constant.

Example 4: Using the total radiation for the month of August for the problem in example 3, what is the estimated total use for the month?

Mean total R_s for August = 12.42 inches

Average $\left(\frac{LE_t}{R_s}\right)_m$ for August (37-60%) $\cong$ 0.71

Estimated total E_t for August = (0.71)(12.42) $\cong$ 8.8 inches.

Estimating Seasonal Evapotranspiration

Solar radiation can also be used to estimate total seasonal E_t. For an entire season equation (19) becomes:

$$\text{Total seasonal } E_t = \frac{\int_0^{100} \left(\frac{LE_t}{R_s}\right)_m R_s \, dS}{100} \times D_s \quad \ldots\ldots\ldots \quad (20)$$

where

D_s is the total days in the season.

Example 5: How much water will irrigated grain sorghum use during an average growing season at Dodge City, Kansas if good irrigation practices are maintained throughout the season? Use the same crop conditions as used in example No. 1.

For convenience, though not necessary, the 137-day growing season will be divided into 10 equal increments 13.7 days each. If desired, smaller increments can be used where $(LE_t/R_s)_m$ changes rapidly. For the 10 increments the following data are obtained from figure 15 and table A-1. (Note: Plotting the $\overline{R}_s$ from table A-1 will simplify obtaining $\overline{R}_s$ values).

(1) Increment S	(2) D	(3) Midpoint S	(4) Date	(5) Avg. $\left(\frac{LE_t}{R_s}\right)_m$	(6) $\overline{R}_s$	Col. 2x5x6
%	Days	%				Inches
0 -10	13.7	5	6/17	0.21	0.44	1.27
10-20	13.7	15	7/1	.29	.45	1.79
20-30	13.7	25	7/14	.44	.43	2.59
30-40	13.7	35	7/28	.62	.43	3.65
40-50	13.7	45	8/11	.73	.41	4.10
50-60	13.7	55	8/24	.69	.39	3.69
60-70	13.7	65	9/7	.61	.36	3.01
70-80	13.7	75	9/21	.50	.31	2.12
80-90	13.7	85	10/4	.37	.28	1.42
90-100	13.7	95	10/18	.25	.25	.86
					Total =	24.50

Total E_t for the season = 24.50 inches

However, if the "dry soil at harvest" curve was used the total for the season would have been 22.36 inches.

Both of the above values are within 5 percent of mean seasonal E_t measured in the area. The latter value may be more common when using an irrigation treatment where irrigations are not made after the hard dough stage (about September 15) because additional irrigations do not affect yields materially and may delay harvest.

Reliability of Estimating Procedure

In the proposed estimating procedure only one of several variables are used with average values for the remaining variables. This means that the estimate would be reliable for longer periods of time and less reliable for very short periods. Also a procedure as shown above should be considered as a first approximation using the energy balance concept. A second or refined estimate can be obtained when the actual A and R_{et} values can be incorporated for each specific period rather than the average as used here.

A preliminary evaluation of equation 17 was made and the results plotted in figure 22. The individual points represent 27 periods of 5-10 days, 20 periods of 11 to 15 days, and 14 periods of more than 16 days. A more detailed comparison will be made when the analysis of all data is completed. In general, the results shown in figure 22 are encouraging. However, until equation (17) can be tested on other data from which the mean curves were developed reliable conclusions cannot be made. Also, as better E_t data are obtained from carefully controlled irrigation experiments in the future with actual R_s values, less variability in the measured (LE_t/R_s) ratios can be expected. However, some variability will always exist because of variations in r, R_{et} and A from mean values.

SUMMARY

Measured evapotranspiration data from various irrigated areas in the western United States obtained during the past 35 years have been collected, screened and preliminary analysis completed. Curves of values of the ratio of evapotranspiration to solar radiation throughout the crop season for 25 crops are being prepared. Preliminary analysis indicates that improved estimates of E_t rates for 5 day periods and longer can be made using simplified energy balance equation. This equation uses mean measured combined values of reflectance, thermal radiation and sensible heat flux in the air. The main parameters used in this equation are solar radiation and percent of the crop growing season.

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TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: PHOENIX, ARIZONA   Latitude: 33°26' N.   Elevation: 1139 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Possible rad.	(5) Standard deviation	(6) Minimum radiation	(7) Maximum radiation	(8) Weekly mean temp.: Mean temperature	(9) Mean maximum temp.	(10) Mean cloud cover 1/	(11) Four-week moving mean 2/: Radiation	(12) Standard deviation	(13) Cloud cover
		In./day	Pct. 3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.185	65	0.028	0.128	0.206	51	64	4.6	0.191	0.028	4.9
2	9	.184	63	.038	.118	.225	55	67	5.8	.196	.031	5.3
3	9	.204	65	.020	.167	.235	52	64	5.7	.210	.031	5.2
4	9	.212	65	.037	.160	.260	53	65	5.0	.228	.028	4.9
5	9	.241	70	.029	.182	.271	54	67	4.4	.245	.031	4.6
6	9	.258	71	.028	.229	.308	55	68	4.5	.266	.034	4.3
7	9	.271	70	.031	.207	.313	57	71	4.5	.282	.037	4.4
8	9	.294	72	.046	.210	.348	54	67	3.9	.302	.037	4.5
9	9	.307	71	.042	.249	.356	57	70	4.5	.324	.036	4.3
10	9	.335	74	.028	.283	.367	61	75	5.0	.343	.035	4.3
11	9	.360	75	.028	.306	.401	59	73	3.7	.364	.030	4.1
12	9	.367	73	.041	.278	.405	62	76	4.1	.384	.031	3.7
13	9	.392	75	.025	.359	.432	64	78	3.6	.406	.031	3.6
14	9	.417	76	.031	.364	.460	66	80	3.4	.421	.029	3.6
15	9	.446	79	.027	.397	.478	68	83	3.1	.439	.029	3.6
16	9	.430	74	.033	.373	.485	71	85	4.1	.452	.029	3.5
17	9	.463	77	.026	.427	.507	70	84	3.5	.460	.029	3.5
18	9	.469	77	.031	.409	.514	72	87	3.2	.475	.028	2.4

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. PHOENIX, ARIZONA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.478	77	0.028	0.419	0.512	74	89	3.2	0.486	0.025	2.9
20	9	.491	77	.027	.465	.540	77	91	3.3	.495	.022	2.8
21	9	.508	79	.016	.475	.528	78	93	1.9	.501	.023	2.7
22	9	.505	78	.018	.474	.525	80	96	2.7	.504	.023	2.1
23	8	.499	76	.030	.453	.539	84	100	2.4	.500	.029	2.4
24	8	.502	77	.029	.461	.539	86	101	1.5	.497	.031	2.0
25	8	.492	75	.037	.432	.530	91	106	1.9	.485	.039	2.1
26	9	.493	75	.027	.455	.541	90	105	2.0	.476	.037	2.5
27	9	.353	70	.061	.366	.536	91	104	3.1	.462	.038	3.1
28	9	.466	72	.021	.439	.506	92	105	2.8	.445	.037	3.6
29	9	.435	68	.043	.361	.489	91	103	4.3	.437	.029	3.9
30	9	.426	68	.023	.395	.459	90	101	4.1	.425	.028	4.5
31	9	.420	68	.027	.389	.467	90	101	4.5	.419	.025	4.4
32	9	.418	69	.020	.382	.454	90	102	4.9	.412	.026	4.5
33	9	.411	69	.031	.357	.454	89	100	4.0	.411	.024	3.8
34	9	.398	69	.025	.353	.428	88	99	4.5	.407	.025	3.0
35	9	.418	75	.019	.390	.448	88	101	1.6	.398	.026	2.5
36	9	.401	74	.025	.364	.429	89	103	1.8	.393	.025	1.8
37	9	.377	72	.036	.296	.408	86	100	2.2	.378	.026	1.8
38	9	.376	75	.019	.352	.409	83	97	1.4	.358	.028	2.0
39	9	.357	75	.026	.314	.394	80	95	1.5	.342	.031	1.9
40	9	.322	71	.032	.275	.366	78	91	2.8	.322	.035	2.3
41	9	.312	72	.048	.213	.351	76	90	2.0	.303	.034	2.7
42	9	.297	73	.033	.221	.329	73	88	2.7	.287	.034	2.7
43	9	.283	74	.021	.245	.307	69	83	3.2	.272	.029	2.9
44	9	.258	71	.034	.201	.299	65	77	2.7	.253	.024	3.3
45	9	.252	73	.026	.197	.288	64	78	3.0	.239	.021	3.2
46	9	.220	68	.015	.203	.253	59	71	4.3	.224	.017	3.3
47	9	.225	72	.010	.210	.241	57	71	2.7	.209	.015	3.6
48	9	.200	67	.018	.172	.229	58	71	3.1	.201	.017	3.4
49	9	.191	67	.015	.167	.210	53	66	4.2	.193	.020	3.9
50	9	.189	68	.024	.157	.227	54	68	3.5	.191	.022	4.0
51	9	.191	69	.022	.143	.213	54	68	4.6	.189	.025	4.1
52	9	.192	69	.025	.129	.209	51	65	3.7	.188	.028	4.7

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: DAVIS, CALIFORNIA   Latitude: 38° 32' N.   Elevation: 50 feet

(1) Solar: week:	(2) Years: of record:	(3) Weekly mean values of daily totals: Radiation	(4) Possible rad.	(5) Standard deviation	(6) Minimum radiation	(7) Maximum radiation	(8) Weekly mean temp.: Mean temperature	(9) Mean maximum temp.	(10) Mean cloud cover[1]	(11) Four-week moving mean[2]: Radiation	(12) Standard deviation	(13) Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.102	44	0.027	0.059	0.142	44	52	7.0	0.104	0.026	7.2
2	9	.096	40	.026	.062	.154	47	54	7.9	.104	.028	7.7
3	9	.103	40	.025	.064	.144	46	52	8.2	.114	.033	7.5
4	9	.114	42	.035	.074	.179	47	54	7.9	.126	.039	7.2
5	9	.144	49	.045	.088	.204	48	57	5.9	.142	.046	6.8
6	8	.144	45	.051	.067	.213	50	58	6.9	.163	.055	6.1
7	8	.167	49	.051	.106	.246	51	61	6.6	.187	.061	5.7
8	8	.196	54	.073	.075	.277	51	60	5.0	.213	.060	5.3
9	8	.241	61	.070	.079	.289	52	63	4.5	.240	.055	4.9
10	9	.245	58	.048	.177	.312	53	65	5.3	.261	.049	5.0
11	9	.278	62	.031	.230	.320	52	64	4.9	.276	.045	5.3
12	9	.277	59	.046	.197	.333	54	67	5.4	.302	.045	5.0
13	9	.304	61	.054	.173	.350	56	67	5.8	.325	.054	4.9
14	9	.349	67	.049	.252	.393	59	73	4.0	.344	.059	4.8
15	9	.371	68	.067	.200	.416	59	73	4.4	.359	.058	4.7
16	9	.353	62	.064	.242	.430	60	74	4.9	.374	.054	4.7
17	9	.365	62	.053	.303	.434	59	72	5.3	.381	.050	4.9
18	9	.407	67	.031	.363	.461	61	74	4.1	.403	.050	4.5

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. DAVIS, CALIFORNIA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.401	65	0.052	0.310	0.465	64	78	5.1	0.425	0.047	4.0
20	9	.440	69	.063	.310	.505	66	80	3.3	.437	.051	3.9
21	9	.452	70	.042	.382	.506	65	79	3.5	.450	.050	3.6
22	9	.457	70	.045	.367	.502	68	84	3.8	.459	.040	3.3
23	8	.453	69	.049	.383	.500	70	86	3.7	.470	.033	2.7
24	8	.475	72	.023	.446	.519	71	87	2.3	.480	.025	2.0
25	8	.498	76	.015	.479	.520	77	94	0.8	.489	.016	1.2
26	9	.493	75	.011	.482	.508	73	90	1.1	.488	.015	1.0
27	9	.488	75	.014	.470	.506	75	94	0.5	.478	.018	1.0
28	9	.471	73	.021	.425	.499	75	94	1.5	.466	.021	1.1
29	9	.459	72	.026	.418	.493	76	96	0.9	.455	.023	.9
30	9	.445	71	.024	.409	.483	78	97	1.3	.446	.020	1.1
31	9	.447	73	.022	.402	.478	75	94	1.0	.436	.017	1.1
32	9	.437	73	.006	.428	.447	75	95	1.0	.424	.017	1.1
33	9	.417	72	.016	.388	.438	73	92	1.2	.409	.016	1.3
34	9	.400	71	.024	.338	.419	73	91	1.1	.385	.018	1.3
35	9	.383	71	.016	.353	.406	72	90	1.8	.373	.017	1.4
36	9	.366	71	.014	.339	.385	74	93	1.1	.353	.019	1.5
37	9	.342	69	.014	.315	.359	71	88	1.7	.333	.019	1.5
38	9	.319	68	.031	.242	.345	70	86	1.3	.309	.021	1.8
39	9	.304	69	.019	.265	.336	71	88	1.8	.282	.029	2.1
40	9	.272	65	.020	.244	.303	67	84	2.4	.260	.028	2.8
41	8	.232	60	.045	.128	.266	65	80	3.0	.238	.030	3.0
42	9	.233	64	.028	.168	.254	64	79	3.9	.217	.030	3.3
43	9	.215	63	.025	.176	.253	62	76	2.7	.200	.027	3.7
44	9	.189	59	.023	.151	.216	59	73	3.4	.173	.031	4.3
45	8	.162	55	.039	.088	.212	58	72	4.7	.152	.037	5.1
46	8	.126	46	.035	.059	179	51	62	6.5	.137	.039	5.5
47	8	.132	51	.049	.040	.181	51	62	5.6	.124	.039	5.8
48	8	.127	52	.033	.081	.173	50	62	5.1	.114	.040	6.1
49	8	.110	47	.038	.070	.165	48	58	6.0	.102	.036	6.7
50	8	.090	39	.040	.034	.144	47	56	7.8	.100	.034	6.8
51	8	.084	37	.033	.029	.110	47	55	7.9	.098	.031	7.1
52	8	.115	51	.024	.079	.147	45	54	5.6	.099	.027	7.1

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: FRESNO, CALIFORNIA Latitude: $36^{\circ} 46'$ N. Elevation: 362 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.			Four-week moving mean[2/]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean max. temp.	Mean cloud cover[1/]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3/]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.112	45	0.033	0.066	0.171	43	52	6.7	0.116	.035	7.1
2	9	.114	44	.037	.071	.189	47	56	7.7	.121	.035	7.6
3	9	.117	43	.034	.056	.153	45	53	8.2	.133	.036	7.3
4	9	.141	48	.035	.112	.220	48	57	7.8	.146	.038	7.0
5	9	.162	52	.037	.097	.203	47	58	5.4	.164	.043	6.5
6	9	.166	50	.047	.100	.231	50	60	6.5	.186	.047	5.7
7	9	.187	52	.054	.096	.282	51	61	6.3	.209	.052	5.5
8	9	.231	61	.052	.151	.306	50	62	4.6	.235	.052	5.1
9	9	.253	62	.055	.145	.312	51	63	4.6	.262	.053	4.7
10	9	.271	60	.046	.228	.354	54	66	4.9	.283	.052	4.6
11	9	.359	65	.060	.180	.366	52	65	4.5	.300	.051	4.8
12	9	.316	67	.045	.244	.382	56	69	4.5	.322	.055	4.7
13	9	.322	64	.052	.224	.393	56	69	5.4	.341	.055	4.6
14	9	.357	67	.062	.229	.428	60	74	4.5	.353	.060	4.6
15	9	.371	67	.061	.229	.434	60	74	4.0	.363	.057	4.5
16	9	.362	63	.064	.233	.443	62	75	4.4	.375	.053	4.3
17	9	.364	61	.040	.296	.406	60	73	5.0	.380	.054	4.5
18	9	.404	67	.045	.325	.473	63	77	3.7	.393	.051	4.3

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. FRESNO, CALIFORNIA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.389	63	0.068	0.297	0.522	65	78	5.0	0.415	0.050	3.7
20	9	.413	65	.052	.320	.496	67	81	3.3	.421	.050	3.5
21	9	.454	70	.036	.407	.507	67	81	2.6	.438	.042	2.9
22	9	.429	66	.045	.342	.500	69	84	2.9	.454	.041	2.5
23	8	.455	69	.035	.409	.499	71	85	2.8	.459	.043	2.0
24	8	.477	73	.048	.416	.547	74	90	1.6	.473	.045	1.5
25	8	.473	72	.045	.421	.543	79	96	0.8	.476	.047	0.9
26	9	.486	74	.051	.417	.568	76	93	0.8	.468	.044	0.9
27	9	.468	72	.044	.403	.537	79	96	0.5	.445	.045	1.1
28	9	.447	69	.037	.385	.494	80	97	1.4	.445	.046	1.1
29	9	.442	69	.048	.363	.505	81	98	1.3	.435	.045	1.3
30	9	.425	67	.056	.323	.511	83	99	1.3	.428	.046	1.1
31	9	.427	69	.038	.380	.512	79	96	1.3	.421	.045	1.0
32	9	.419	70	.041	.364	.460	80	97	0.6	.414	.042	1.0
33	9	.412	71	.047	.351	.477	79	95	0.9	.403	.041	1.1
34	9	.397	70	.043	.333	.471	77	93	1.3	.390	.041	1.4
35	9	.386	71	.034	.340	.439	76	93	1.7	.376	.039	1.4
36	9	.367	69	.041	.307	.431	77	94	1.8	.360	.038	1.4
37	9	.354	69	.037	.296	.409	74	89	0.9	.342	.037	1.4
38	9	.332	69	.041	.270	.386	72	87	1.2	.323	.037	1.4
39	9	.317	70	.030	.264	.355	73	89	1.6	.301	.040	1.9
40	9	.290	68	.042	.219	.337	69	84	2.0	.280	.034	2.5
41	9	.265	66	.048	.169	.334	66	81	2.8	.261	.035	2.6
42	9	.249	66	.016	.226	.271	65	80	3.5	.241	.032	2.8
43	9	.239	67	.033	.203	.285	61	76	2.1	.222	.026	3.1
44	9	.212	63	.031	.161	.257	58	73	2.9	.201	.028	3.5
45	9	.189	60	.024	.146	.217	59	73	3.8	.179	.028	4.1
46	9	.164	56	.024	.125	.205	51	62	5.2	.161	.028	4.5
47	9	.152	56	.036	.064	.189	49	62	4.5	.147	.029	4.9
48	9	.140	54	.030	.082	.167	50	62	4.7	.132	.032	5.3
49	9	.133	53	.027	.082	.180	47	58	5.2	.117	.030	6.1
50	9	.102	42	.034	.051	.140	47	56	6.9	.113	.031	6.4
51	9	.094	39	.029	.039	.144	46	54	7.8	.108	.033	6.8
52	9	.122	50	.036	.077	.185	44	54	5.8	.110	.034	7.0

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: GRAND JUNCTION, COLORADO   Latitude: 39° 07' N.   Elevation: 4848 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.		Mean	Four-week moving mean 2/		
Solar week	Years of record	Radiation	Poss. rad.	Std. dev.	Min. rad.	Max. rad.	Mean temp.	Mean max. temp.	cloud cover 1/	Radiation	Std. dev.	Cloud cover
		In./day	Pct. 3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.148	65	0.020	0.118	0.184	28	38	6.3	0.150	0.024	6.0
2	9	.148	62	.029	.092	.189	32	41	6.2	.155	.025	6.4
3	9	.159	63	.024	.111	.201	29	38	6.5	.165	.028	6.3
4	9	.163	61	.028	.123	.207	30	40	6.7	.180	.031	6.2
5	9	.190	66	.030	.150	.225	30	40	5.7	.192	.030	6.4
6	9	.207	66	.044	.124	.260	32	42	6.0	.211	.033	6.3
7	9	.208	62	.016	.184	.229	35	45	7.3	.229	.039	6.3
8	9	.239	66	.043	.163	.293	34	44	6.2	.251	.037	6.1
9	9	.263	68	.051	.169	.332	34	44	5.9	.270	.045	5.8
10	9	.296	71	.036	.246	.357	40	51	5.0	.282	.056	5.8
11	9	.283	64	.048	.203	.354	40	51	6.2	.300	.060	5.6
12	9	.286	60	.090	.155	.433	44	56	6.2	.310	.069	6.1
13	8	.333	67	.067	.237	.428	46	58	5.2	.328	.069	5.8
14	8	.336	64	.072	.208	.424	47	60	6.7	.351	.059	5.5
15	8	.356	65	.048	.256	.398	50	62	5.2	.358	.053	5.9
16	9	.380	67	.048	.326	.473	54	68	5.0	.371	.042	5.6
17	9	.361	61	.046	.297	.439	53	66	6.7	.383	.046	5.7
18	9	.387	64	.025	.355	.433	56	69	5.6	.385	.053	6.0

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. GRAND JUNCTION, COLORADO (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	8	0.404	65	0.066	0.330	0.500	61	74	5.4	0.402	0.051	5.6
20	7	.387	61	.074	.289	.504	61	74	6.4	.415	.071	6.9
21	7	.430	67	.039	.389	.492	64	77	5.2	.432	.067	6.6
22	7	.439	67	.104	.214	.518	67	81	3.8	.449	.057	6.0
23	7	.471	72	.049	.426	.535	71	85	4.5	.466	.054	4.0
24	6	.455	69	.038	.383	.484	72	86	4.5	.477	.039	3.7
25	6	.499	76	.025	.457	.525	77	93	3.1	.477	.038	3.4
26	8	.485	74	.043	.415	.541	77	93	2.8	.478	.037	3.3
27	8	.470	72	.046	.407	.553	77	91	3.3	.466	.043	3.6
28	8	.457	71	.034	.405	.487	79	93	4.2	.453	.042	4.1
29	8	.453	71	.048	.366	.502	79	93	4.2	.441	.037	4.4
30	8	.434	69	.039	.348	.462	79	92	4.6	.436	.035	4.3
31	7	.419	68	.026	.387	.468	78	91	4.6	.421	.031	4.2
32	7	.440	74	.028	.386	.467	77	91	3.6	.407	.031	4.2
33	8	.392	68	.032	.339	.438	75	88	4.1	.402	.037	3.8
34	8	.376	67	.039	.305	.415	73	86	4.4	.383	.044	3.7
35	8	.398	74	.050	.299	.457	72	86	3.2	.367	.045	3.6
36	6	.367	71	.055	.277	.414	73	87	3.0	.356	.046	3.3
37	7	.328	67	.036	.269	.369	70	83	3.7	.336	.046	3.3
38	8	.333	72	.043	.237	.373	65	79	3.3	.319	.043	3.3
39	8	.318	73	.051	.213	.360	63	77	3.0	.304	.049	3.3
40	8	.296	72	.042	.233	.339	62	75	3.1	.283	.048	3.5
41	8	.269	70	.059	.175	.334	58	71	3.8	.265	.043	3.7
42	9	.250	69	.041	.169	.284	55	68	4.1	.234	.042	4.1
43	9	.222	66	.028	.183	.272	50	62	3.9	.216	.032	4.1
44	9	.196	62	.039	.130	.232	45	57	4.5	.194	.030	4.6
45	9	.197	68	.021	.165	.230	43	55	4.0	.182	.026	4.7
46	9	.162	60	.031	.113	.210	39	50	5.9	.173	.022	4.7
47	9	.173	68	.012	.150	.189	34	44	4.5	.159	.021	5.1
48	9	.162	68	.023	.115	.189	32	43	4.3	.156	.018	5.0
49	9	.140	61	.020	.108	.173	30	40	5.8	.147	.023	5.3
50	9	.150	67	.018	.125	.178	30	39	5.4	.143	.023	5.3
51	9	.138	62	.030	.036	.175	32	41	5.9	.145	.023	5.5
52	9	.143	64	.022	.115	.176	29	39	5.1	.144	.025	5.9

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: BOISE, IDAHO   Latitude: 34° 34' N.   Elevation: 2895 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.		Mean	Four-week moving mean[2]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean max. temp.	cloud cover[1]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.092	50	0.022	0.065	0.132	29	36	7.7	0.088	0.020	7.8
2	8	.084	43	.014	.061	.108	34	42	7.8	.092	.026	8.3
3	7	.087	38	.035	.039	.144	30	38	8.6	.102	.029	8.1
4	8	.107	48	.032	.066	.145	30	38	8.4	.114	.032	7.8
5	7	.129	54	.033	.088	.187	32	41	6.7	.127	.031	7.8
6	7	.135	51	.029	.100	.169	35	43	7.0	.144	.035	7.4
7	7	.136	46	.031	.090	.183	36	43	8.3	.162	.038	7.4
8	7	.176	55	.047	.127	.275	38	47	7.4	.182	.044	8.0
9	8	.200	56	.043	.135	.252	36	45	6.5	.205	.045	6.9
10	8	.216	57	.054	.149	.308	40	50	6.7	.223	.046	6.7
11	8	.227	55	.037	.196	.298	40	50	6.7	.233	.049	6.9
12	8	.250	57	.049	.185	.339	44	56	6.7	.258	.048	6.8
13	8	.240	51	.055	.164	.343	44	55	7.7	.285	.046	6.6
14	8	.316	64	.053	.232	.378	46	59	6.2	.303	.051	6.5
15	8	.333	65	.027	.283	.365	48	60	5.8	.322	.048	6.5
16	8	.320	59	.069	.199	.418	50	62	6.5	.335	.048	6.3
17	8	.319	56	.042	.266	.377	49	61	7.3	.346	.056	6.5
18	9	.367	62	.053	.260	.445	53	66	5.5	.368	.050	6.2

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. BOISE, IDAHO (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.377	62	0.057	0.272	0.429	56	69	6.5	0.386	0.052	5.9
20	9	.409	65	.046	.347	.462	58	71	5.4	.395	.057	6.0
21	9	.390	61	.053	.315	.453	58	71	6.0	.401	.061	5.8
22	9	.401	62	.070	.278	.478	62	75	6.0	.404	.056	5.6
23	8	.404	61	.075	.277	.497	63	77	5.5	.421	.057	4.9
24	8	.419	64	.026	.387	.465	65	79	5.0	.436	.052	4.3
25	8	.462	70	.056	.336	.524	69	84	3.0	.455	.039	3.4
26	9	.460	70	.049	.388	.529	67	81	3.8	.460	.042	2.9
27	9	.479	73	.023	.436	.515	70	86	1.9	.457	.037	2.7
28	9	.437	68	.041	.367	.482	77	92	2.9	.448	.030	2.4
29	9	.450	71	.035	.410	.520	76	92	2.1	.434	.029	2.5
30	9	.427	69	.019	.397	.449	77	93	2.7	.428	.025	2.3
31	9	.421	69	.021	.382	.455	74	90	2.1	.414	.022	2.5
32	9	.416	71	.025	.363	.443	74	91	2.4	.398	.025	2.7
33	9	.393	70	.025	.361	.443	73	88	2.9	.382	.029	3.0
34	9	.360	67	.028	.326	.421	69	84	3.4	.362	.031	3.2
35	9	.359	70	.038	.300	.399	67	82	3.3	.341	.033	3.2
36	9	.334	68	.034	.265	.390	68	83	3.0	.325	.035	3.1
37	9	.311	67	.032	.255	.356	66	80	3.0	.306	.032	3.1
38	9	.297	68	.034	.233	.355	60	74	3.3	.286	.034	3.3
39	9	.281	70	.029	.234	.328	60	75	3.1	.259	.035	3.9
40	9	.255	68	.040	.158	.303	57	72	3.7	.236	.033	4.2
41	9	.201	58	.037	.137	.267	55	67	5.5	.210	.034	4.5
42	9	.206	64	.025	.162	.253	53	67	4.4	.186	.032	4.9
43	9	.179	60	.035	.123	.225	48	61	4.6	.171	.029	5.1
44	9	.157	58	.031	.106	.195	43	55	5.3	.146	.030	5.7
45	9	.142	58	.024	.115	.177	43	56	6.2	.130	.031	6.0
46	9	.105	46	.030	.058	.154	36	45	6.8	.114	.032	6.2
47	9	.117	56	.039	.063	.178	38	48	5.6	.100	.033	6.5
48	9	.092	47	.037	.040	.136	33	42	6.2	.094	.030	6.7
49	9	.086	46	.026	.055	.134	32	40	7.4	.086	.029	7.0
50	9	.081	45	.020	.042	.104	33	40	7.4	.085	.022	7.2
51	9	.084	47	.032	.017	.128	34	42	7.0	.086	.021	7.3
52	9	.087	49	.010	.077	.105	30	37	7.1	.087	.020	7.4

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: DODGE CITY, KANSAS — Latitude: 37° 46' N. — Elevation: 2625 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Poss. rad.	(5) Std. dev.	(6) Min. rad.	(7) Max. rad.	(8) Weekly mean temp.: Mean temp.	(9) Mean max. temp.	(10) Mean cloud cover 1/	(11) Four-week moving mean 2/: Radiation	(12) Std. dev.	(13) Cloud cover
		In./day	Pct. 3/	In./day	In./day	In/day	Deg. F.	Deg. F.	Tenths	In./day	In./day	Tenths
1	9	0.167	69	0.022	0.129	0.199	33	45	4.5	0.168	0.028	4.9
2	9	.170	68	.038	.105	.210	35	47	5.0	.173	.031	5.4
3	8	.173	65	.025	.131	.207	27	38	5.7	.179	.036	5.7
4	8	.182	65	.037	.110	.239	29	40	6.3	.187	.041	5.9
5	8	.190	63	.043	.114	.246	33	44	6.0	.199	.048	5.8
6	8	.205	64	.058	.090	.278	33	44	5.7	.213	.049	5.7
7	8	.218	63	.055	.120	.277	37	50	5.3	.228	.051	5.7
8	8	.240	64	.039	.164	.272	35	47	5.9	.242	.051	5.9
9	8	.249	62	.051	.178	.329	36	48	6.1	.258	.049	6.3
10	8	.263	62	.060	.166	.333	40	51	6.3	.271	.058	6.4
11	8	.282	63	.047	.219	.334	39	52	7.0	.285	.063	6.3
12	8	.288	60	.076	.166	.373	42	54	6.3	.303	.068	6.0
13	8	.305	61	.068	.197	.371	46	59	5.5	.314	.069	5.7
14	8	.336	64	.079	.227	.415	49	62	5.3	.338	.069	5.4
15	8	.328	60	.051	.255	.405	49	61	5.8	.356	.061	5.4
16	8	.384	67	.078	.233	.467	57	71	5.0	.354	.058	5.7
17	8	.377	64	.036	.313	.428	58	72	5.6	.364	.064	5.8
18	8	.328	54	.068	.236	.443	57	68	6.5	.363	.054	6.2

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. DODGE CITY, KANSAS (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	8	0.369	60	0.073	0.241	0.470	61	72	6.0	0.369	0.060	6.1
20	8	.376	60	.038	.346	.465	63	75	6.7	.401	.051	5.7
21	8	.402	63	.061	.294	.472	67	79	5.1	.416	.051	5.5
22	8	.455	70	.031	.397	.486	71	84	5.2	.422	.060	5.1
23	7	.429	66	.071	.286	.486	73	85	5.0	.440	.053	4.7
24	8	.401	61	.077	.310	.598	75	86	5.1	.440	.054	4.3
25	8	.474	72	.031	.420	.524	76	89	3.4	.441	.057	4.1
26	9	.458	70	.036	.401	.528	79	92	3.6	.451	.048	4.0
27	9	.434	66	.085	.272	.562	79	91	4.5	.434	.049	4.3
28	9	.439	68	.040	.376	.496	78	90	4.5	.432	.052	4.5
29	9	.406	64	.035	.371	.483	79	90	5.7	.434	.039	4.3
30	9	.448	71	.047	.383	.520	80	93	3.3	.429	.034	4.3
31	10	.444	72	.032	.401	.512	82	95	3.5	.425	.036	3.9
32	9	.416	69	.023	.372	.456	79	91	4.5	.404	.037	4.3
33	9	.390	67	.041	.325	.477	79	91	4.3	.395	.036	4.1
34	9	.364	65	.053	.287	.479	78	90	4.7	.382	.041	3.7
35	8	.401	74	.027	.371	.434	79	92	3.1	.371	.044	3.4
36	8	.373	71	.042	.313	.432	75	88	2.9	.359	.040	3.2
37	8	.345	69	.056	.242	.415	72	85	3.0	.334	.048	3.3
38	9	.317	67	.036	.250	.377	70	82	3.9	.309	.054	3.6
39	9	.302	68	.060	.208	.372	66	78	3.4	.292	.056	3.8
40	9	.276	66	.063	.169	.341	63	75	4.2	.277	.061	3.8
41	9	.273	69	.064	.121	.341	62	75	3.7	.260	.057	3.9
42	9	.257	68	.058	.154	.310	57	70	3.9	.245	.050	4.1
43	9	.234	67	.042	.170	.283	53	66	3.7	.228	.047	4.2
44	8	.217	67	.038	.164	.272	49	61	4.9	.212	.042	4.3
45	9	.204	68	.051	.107	.256	45	56	4.3	.199	.039	4.5
46	9	.192	68	.036	.112	.230	44	57	4.4	.121	.034	4.5
47	9	.182	68	.029	.127	.221	41	53	4.4	.175	.028	4.7
48	9	.172	68	.019	.143	.200	36	49	4.7	.167	.026	4.8
49	9	.156	64	.030	.115	.191	36	47	5.1	.162	.022	4.7
50	9	.160	68	.026	.113	.193	33	45	5.0	.159	.025	4.6
51	8	.159	68	.015	.139	.186	35	47	4.0	.162	.023	4.5
52	9	.161	69	.027	.106	.203	34	46	4.4	.164	.026	4.5

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: GLASGOW, MONTANA — Latitude: 48° 13' N. — Elevation: 2294 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.			Four-week moving mean[2/]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.	Mean cloud cover[1/]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	6	0.091			0.067	0.102			6.1	0.091		6.4
2	6	.097			.083	.117			6.6	.100		6.6
3	6	.105			.087	.119			6.3	.109		6.9
4	6	.108			.035	.146			7.4	.119		7.1
5	6	.128			.118	.141			7.2	.138		7.3
6	6	.136			.103	.165			7.5	.162		6.9
7	6	.179			.163	.206			7.1	.184		6.8
8	6	.205			.185	.235			5.6	.211		6.6
9	6	.216			.187	.251			7.0	.232		6.5
10	5	.242			.219	.263			6.8	.250		6.8
11	5	.265			.255	.287			6.8	.267		7.0
12	5	.279			.261	.294			6.7	.277		7.2
13	5	.281			.240	.352			7.6	.292		7.1
14	7	.282			.240	.349			7.7	.305		7.1
15	7	.325			.291	.358			6.5	.313		7.2
16	7	.332			.275	.397			6.8	.326		7.2
17	7	.314			.265	.408			7.9	.346		7.1
18	7	.331			.189	.365			7.5	.363		6.9

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. GLASGOW, MONTANA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	7	0.404			0.326	0.471			5.9	0.386		6.3
20	6	.402			.344	.465			6.2	.398		6.1
21	6	.408			.339	.484			5.7	.396		6.3
22	6	.380			.332	.446			6.5	.395		6.3
23	8	.394			.363	.459			6.7	.399		6.4
24	5	.400			.351	.506			6.1	.407		6.1
25	5	.420			.373	.508			6.2	.417		6.0
26	5	.413			.323	.433			5.5	.426		5.5
27	6	.433			.321	.522			6.1	.434		4.7
28	7	.436			.390	.497			4.3	.437		4.4
29	8	.454			.391	.537			3.1	.431		3.8
30	8	.424			.362	.495			4.1	.423		3.7
31	8	.409			.352	.462			3.8	.403		3.9
32	8	.405			.373	.469			3.7	.385		3.9
33	9	.375			.332	.429			4.2	.352		4.2
34	9	.350			.283	.411			3.8	.330		4.5
35	9	.280			.179	.378			5.2	.306		4.6
36	9	.317			.278	.364			4.8	.277		5.5
37	8	.276			.169	.327			4.7	.266		5.6
38	8	.236			.168	.294			7.3	.240		5.8
39	8	.235			.149	.305			5.7	.222		6.2
40	7	.213			.185	.275			5.4	.204		5.7
41	7	.205			.171	.242			6.5	.201		5.5
42	7	.162			.111	.237			5.3	.168		5.9
43	6	.159			.117	.234			5.0	.146		6.1
44	6	.145			.112	.187			7.0	.132		6.6
45	6	.119			.096	.159			7.1	.114		7.3
46	7	.105			.079	.136			7.4	.102		7.2
47	7	.087			.063	.103			7.6	.092		7.1
48	7	.095			.078	.109			6.8	.085		7.3
49	6	.082			.074	.092			6.8	.082		6.9
50	6	.076			.061	.087			8.2	.076		6.8
51	6	.075			.062	.087			5.8	.078		6.7
52	6	.071			.044	.087			6.5	.084		6.2

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: GREAT FALLS, MONTANA Latitude: 49° 29' N. Elevation: 3692 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Solar week	Years of record	Weekly mean values of daily totals					Weekly mean temp.		Mean cloud cover 1/	Four-week moving mean 2/		
		Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.		Radiation	Standard deviation	Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	7	0.085			0.067	0.108			6.7	0.087		6.7
2	7	.087			.060	.114			6.7	.092		6.9
3	7	.095			.074	.111			6.7	.103		7.1
4	7	.099			.077	.139			7.7	.113		7.2
5	7	.122			.091	.159			7.2	.127		7.4
6	8	.136			.095	.180			7.3	.149		7.3
7	8	.149			.111	.194			7.5	.170		7.3
8	8	.188			.117	.229			7.2	.190		7.3
9	7	.208			.190	.249			7.1	.212		7.1
10	7	.214			.174	.186			7.3	.229		7.0
11	8	.239			.210	.281			6.8	.244		7.1
12	7	.254			.192	.290			6.8	.259		6.9
13	8	.269			.229	.321			7.3	.279		6.8
14	7	.273			.167	.346			6.9	.291		6.9
15	7	.322			.381	.371			6.1	.296		7.1
16	7	.302			.229	.391			7.3	.306		7.2
17	7	.287			.225	.362			8.0	.313		7.3
18	7	.315			.215	.373			7.3	.330		6.9

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. GREAT FALLS, MONTANA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	7	0.349			0.274	0.441			6.7	0.345		6.7
20	7	.371			.289	.476			5.8	.361		6.5
21	7	.344			.259	.440			7.0	.370		6.5
22	7	.379			.309	.442			6.4	.368		6.5
23	7	.387			.311	.506			6.6	.391		6.2
24	7	.387			.322	.433			6.2	.399		6.0
25	7	.411			.345	.493			5.7	.407		5.6
26	7	.411			.320	.484			5.4	.415		5.1
27	8	.418			.231	.551			5.0	.423		4.5
28	8	.420			.333	.501			4.3	.431		4.1
29	8	.445			.405	.475			3.5	.429		3.8
30	7	.439			.313	.543			3.6	.423		3.8
31	8	.411			.337	.462			3.7	.401		4.0
32	7	.397			.368	.437			4.5	.379		4.2
33	8	.357			.307	.438			4.3	.359		4.5
34	8	.350			.281	.412			4.3	.336		4.7
35	8	.329			.263	.399			4.8	.315		5.1
36	8	.308			.272	.341			5.2	.295		5.2
37	8	.272			.216	.285			5.9	.267		5.4
38	7	.270			.202	.321			4.9	.243		5.6
39	8	.218			.113	.293			5.7	.227		5.6
40	9	.212			.118	.274			5.9	.200		5.9
41	9	.200			.134	.246			5.9	.184		5.8
42	9	.170			.108	.222			6.1	.163		6.0
43	9	.156			.115	.197			5.3	.142		6.3
44	9	.125			.113	.173			6.6	.125		6.6
45	9	.117			.101	.147			7.2	.109		7.1
46	9	.105			.081	.129			7.4	.101		7.2
47	9	.088			.042	.135			7.1	.091		7.2
48	8	.093			.069	.122			7.0	.084		7.1
49	9	.080			.039	.104			7.2	.080		7.0
50	9	.074			.057	.099			7.1	.077		7.0
51	9	.074			.051	.100			6.7	.078		7.9
52	9	.079			.059	.111			6.9	.081		6.7

TABLE A1.-- Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: ELY, NEVADA Latitude: 39° 17' N. Elevation: 6262 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.			Four-week moving mean[2/]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.	Mean cloud cover[1/]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	6	0.148			0.123	0.166			6.5	0.148		6.5
2	6	.141			.120	.155			7.1	.153		7.0
3	6	.156			.121	.172			6.8	.166		6.5
4	6	.166			.148	.186			7.5	.183		6.3
5	7	.202			.167	.245			4.7	.197		6.4
6	7	.206			.183	.219			6.4	.219		6.0
7	8	.214			.181	.234			7.1	.237		6.1
8	8	.253			.208	.297			5.8	.260		5.9
9	8	.276			.200	.328			5.2	.285		5.5
10	9	.296			.245	.357			5.3	.303		5.5
11	9	.315			.257	.368			5.5	.319		5.8
12	9	.325			.233	.397			6.1	.337		6.0
13	9	.340			.281	.429			6.4	.359		5.9
14	8	.367			.285	.413			5.9	.375		5.9
15	8	.406			.355	.433			5.2	.381		5.9
16	9	.387			.271	.477			6.0	.392		6.1
17	9	.365			.291	.436			7.2	.393		6.4
18	9	.411			.343	.486			6.0	.401		6.3

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. ELY, NEVADA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.407			0.273	0.473			6.3	0.416		5.9
20	9	.421			.317	.468			5.7	.421		5.8
21	9	.423			.325	.514			5.8	.431		5.5
22	9	.433			.269	.519			5.5	.444		5.1
23	9	.449			.359	.526			4.9	.462		4.5
24	9	.472			.423	.529			4.4	.483		3.7
25	9	.495			.410	.558			3.0	.491		3.1
26	9	.515			.467	.566			2.5	.483		3.1
27	10	.481			.297	.548			2.6	.465		3.7
28	10	.441			.343	.462			4.4	.439		4.2
29	10	.422			.348	.496			5.1	.423		4.7
30	10	.410			.332	.471			4.8	.421		4.4
31	10	.418			.359	.475			4.6	.416		4.1
32	10	.433			.365	.470			3.2	.415		3.9
33	10	.403			.361	.462			4.0	.413		3.6
34	10	.408			.339	.470			4.0	.400		3.6
35	10	.409			.357	.437			3.2	.391		3.3
36	10	.380			.279	.419			3.2	.371		3.2
37	10	.366			.266	.407			2.7	.349		3.3
38	10	.328			.287	.371			3.7	.333		3.2
39	10	.322			.277	.351			3.5	.313		3.4
40	9	.316			.275	.339			2.9	.295		3.5
41	9	.283			.220	.325			3.4	.270		3.8
42	9	.256			.177	.297			4.2	.247		4.1
43	9	.224			.195	.273			4.6	.229		4.3
44	9	.226			.185	.243			4.1	.208		4.9
45	9	.211			.183	.237			4.4	.197		4.9
46	9	.170			.125	.207			6.7	.183		4.9
47	9	.179			.149	.207			4.6	.166		5.4
48	9	.172			.127	.189			4.0	.160		5.2
49	9	.209			.105	.162			6.2	.151		5.5
50	9	.151			.121	.171			5.9	.145		6.0
51	9	.139			.091	.175			6.1	.147		6.1
52	9	.148			.117	.176			5.7	.144		6.3

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: BISMARCK, NORTH DAKOTA   Latitude: 46° 46' N.   Elevation: 1677 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Poss. rad.	(5) Std. dev.	(6) Min. rad.	(7) Max. rad.	(8) Weekly mean temp.: Mean temp.	(9) Mean max. temp.	(10) Mean cloud cover 1/	(11) Four-week moving mean 2/: Radiation	(12) Std. dev.	(13) Cloud cover
		In./day	Pct. 3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.096	61	0.013	0.078	0.116	14	25	6.3	0.094	0.018	6.8
2	9	.091	56	.018	.069	.123	15	26	7.3	.103	.017	6.9
3	9	.108	60	.019	.062	.124	7	16	6.9	.113	.020	7.1
4	9	.118	61	.019	.093	.145	5	14	6.9	.126	.020	7.0
5	9	.133	62	.024	.098	.167	12	23	7.2	.142	.019	6.9
6	9	.146	61	.018	.118	.172	14	24	6.9	.162	.020	6.7
7	9	.171	65	.016	.146	.195	16	25	6.6	.181	.024	6.5
8	9	.196	67	.023	.160	.230	16	27	6.0	.199	.025	6.7
9	9	.209	65	.039	.119	.254	18	28	6.6	.228	.028	6.7
10	9	.218	62	.023	.177	.247	23	33	7.4	.231	.030	7.0
11	9	.253	66	.026	.227	.294	24	34	6.7	.247	.033	7.0
12	9	.243	59	.032	.211	.287	32	41	7.3	.258	.034	7.0
13	9	.275	61	.049	.191	.335	36	47	6.5	.279	.037	7.1
14	9	.259	54	.028	.213	.298	39	50	7.4	.297	.046	7.1
15	9	.339	67	.038	.300	.399	42	56	7.4	.301	.045	7.5
16	9	.316	59	.069	.202	.394	44	57	7.2	.317	.054	7.4
17	9	.291	52	.044	.227	.377	43	55	8.0	.331	.058	7.0
18	9	.323	55	.066	.203	.392	48	60	6.9	.347	.056	6.8

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. BISMARCK, NORTH DAKOTA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.393	65	0.055	0.320	0.470	54	67	6.0	0.368	0.065	6.3
20	9	.383	62	.059	.281	.471	56	69	6.2	.383	.063	6.1
21	9	.374	59	.079	.236	.497	58	71	5.9	.374	.072	6.3
22	9	.383	59	.060	.318	.471	61	73	6.5	.375	.070	6.2
23	9	.355	54	.090	.205	.462	63	75	6.5	.383	.063	6.2
24	9	.387	59	.053	.305	.453	66	77	6.0	.393	.058	5.9
25	9	.404	61	.047	.356	.488	64	77	5.9	.407	.054	5.5
26	10	.424	65	.043	.351	.497	68	82	5.1	.415	.054	5.2
27	9	.414	63	.071	.290	.487	68	79	4.9	.420	.050	4.9
28	9	.419	65	.055	.342	.507	72	85	5.0	.415	.052	4.7
29	9	.423	67	.031	.371	.454	73	87	4.6	.407	.048	4.7
30	9	.406	66	.053	.307	.482	73	88	4.1	.396	.043	4.5
31	9	.378	63	.054	.315	.462	73	86	5.0	.378	.043	4.7
32	9	.375	65	.035	.326	.431	71	85	4.4	.359	.039	4.9
33	9	.354	64	.030	.304	.400	71	85	5.2	.341	.045	4.9
34	9	.340	65	.034	.298	.400	71	85	4.8	.320	.043	5.2
35	9	.294	59	.079	.134	.375	67	79	5.4	.300	.049	5.1
36	9	.293	62	.028	.249	.329	63	77	5.5	.276	.054	5.4
37	9	.273	61	.055	.173	.331	60	75	4.8	.263	.046	5.4
38	9	.244	59	.053	.169	.315	55	68	6.0	.247	.047	5.2
39	9	.241	63	.046	.162	.291	54	69	5.2	.226	.046	5.4
40	9	.228	65	.035	.152	.262	51	66	4.7	.213	.039	5.1
41	9	.191	59	.049	.097	.242	49	63	5.7	.190	.035	5.3
42	9	.192	65	.025	.140	.220	47	62	4.9	.166	.031	5.8
43	9	.150	57	.030	.115	.207	41	54	5.7	.149	.024	6.0
44	9	.130	55	.019	.098	.153	38	49	6.9	.125	.024	6.6
45	9	.123	57	.023	.069	.145	34	45	6.4	.111	.022	7.1
46	9	.097	49	.024	.063	.132	29	40	7.5	.102	.021	7.1
47	9	.094	53	.020	.049	.115	28	38	7.4	.093	.019	7.2
48	9	.094	56	.017	.067	.125	20	30	7.0	.090	.016	7.1
49	9	.086	55	.015	.073	.110	18	28	6.8	.089	.015	7.0
50	9	.087	58	.014	.067	.103	20	30	7.2	.084	.017	7.0
51	9	.081	57	.013	.058	.104	20	30	7.1	.086	.015	6.9
52	9	.080	55	.021	.045	[illegible]	19	30	6.8	.087	.016	6.9

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: STILLWATER, OKLAHOMA   Latitude: 36° 08' N.   Elevation: 910 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.			Four-week moving mean[2]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.	Mean cloud cover[1]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	7	0.131			0.082	0.195			6.1	0.142		6.1
2	7	.143			.116	.200			6.3	.137		6.4
3	7	.145			.082	.189			6.5	.140		6.4
4	7	.128			.038	.169			6.7	.147		6.6
5	7	.142			.097	.230			6.9	.161		6.5
6	7	.175			.105	.235			6.2	.178		6.4
7	7	.199			.127	.279			6.0	.204		6.1
8	9	.195			.101	.251			6.6	.218		6.1
9	9	.246			.196	.293			5.8	.235		6.1
10	9	.233			.129	.325			6.1	.248		5.7
11	9	.265			.187	.327			5.9	.261		5.7
12	8	.247			.225	.341			5.2	.279		5.5
13	9	.298			.164	.358			5.8	.288		5.6
14	8	.306			.242	.387			5.1	.302		5.8
15	8	.301			.220	.354			6.4	.309		5.9
16	8	.303			.192	.402			5.8	.318		6.2
17	8	.325			.277	.392			6.5	.317		6.5
18	8	.343			.267	.410			6.2	.322		6.7

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. STILLWATER, OKLAHOMA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	8	0.296			0.186	0.389			7.3	0.327		6.5
20	8	.325			.178	.451			6.6	.337		6.4
21	8	.344			.231	.432			6.1	.358		5.9
22	7	.381			.232	.459			5.6	.385		5.4
23	8	.380			.327	.432			5.3	.406		5.0
24	8	.435			.399	.474			4.5	.413		4.7
25	8	.430			.363	.484			4.6	.425		4.6
26	8	.406			.311	.471			4.6	.412		4.8
27	9	.431			.315	.524			4.6	.398		5.0
28	9	.382			.291	.495			5.4	.398		4.9
29	9	.373			.225	.481			5.4	.387		5.0
30	8	.405			.315	.463			4.4	.385		5.0
31	8	.388			.328	.420			4.8	.381		4.7
32	9	.374			.305	.468			5.4	.370		4.6
33	9	.359			.330	.419			4.0	.365		4.3
34	9	.360			.271	.444			4.1	.354		3.9
35	8	.367			.291	.423			3.6	.343		3.9
36	8	.328			.240	.417			3.8	.336		3.9
37	8	.319			.163	.403			4.3	.318		3.9
38	8	.328			.276	.372			3.7	.297		4.0
39	8	.298			.180	.370			4.0	.282		3.9
40	8	.245			.141	.323			4.1	.258		4.3
41	7	.258			.189	.303			3.7	.236		4.3
42	8	.334			.187	.283			5.2	.222		4.7
43	7	.207			.105	.281			4.4	.204		4.9
44	7	.189			.149	.232			5.7	.190		4.9
45	9	.185			.124	.219			4.3	.181		4.9
46	9	.180			.105	.215			5.0	.173		4.8
47	9	.168			.117	.201			4.8	.165		5.0
48	9	.158			.120	.219			5.0	.155		5.1
49	8	.154			.133	.179			5.1	.145		5.3
50	8	.139			.072	.177			5.5	.143		5.3
51	8	.130			.093	.177			5.5	.137		5.6
52	8	.148			.069	.214			5.3	.138		5.8

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: ASTORIA, OREGON Latitude: 46° 09' N. Elevation: 22 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Solar: week	Years of record	Weekly mean values of daily totals					Weekly mean temp.		Mean cloud cover[1]	Four-week moving mean[2]		
		Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.		Radiation	Standard deviation	Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	7	0.063			0.027	0.092			8.7	0.059		8.5
2	7	.058			.032	.078			8.7	.061		8.6
3	7	.058			.035	.087			8.6	.065		8.5
4	8	.066			.024	.135			8.4	.076		8.5
5	8	.079			.055	.109			8.5	.087		8.4
6	8	.101			.044	.142			8.5	.101		8.4
7	7	.103			.053	.169			8.3	.119		8.1
8	7	.119			.088	.209			8.4	.131		8.1
9	8	.151			.082	.203			7.3	.154		7.9
10	8	.152			.129	.187			8.2	.169		7.8
11	8	.193			.165	.300			7.5	.180		8.1
12	8	.182			.135	.238			8.2	.203		8.0
13	7	.193			.111	.243			8.7	.209		8.2
14	7	.242			.171	.328			7.5	.225		8.2
15	7	.219			.152	.287			8.5	.248		7.9
16	7	.245			.185	.351			8.0	.267		7.9
17	7	.287			.153	.337			7.6	.289		7.7
18	6	.315			.262	.359			7.6	.310		7.7

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. ASTORIA, OREGON (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	8	0.311			0.240	0.375			7.7	0.323		7.7
20	8	.326			.200	.424			7.7	.326		7.8
21	7	.340			.280	.423			7.6	.319		7.8
22	7	.327			.249	.386			8.1	.315		7.9
23	7	.284			.225	.454			7.8	.316		7.9
24	7	.311			.263	.365			8.1	.311		7.9
25	8	.341			.247	.429			7.6	.330		7.7
26	8	.308			.253	.395			8.2	.337		7.4
27	7	.361			.243	.422			6.9	.343		7.0
28	7	.336			.265	.347			7.1	.357		6.5
29	7	.366			.277	.445			5.9	.349		6.3
30	7	.366			.221	.439			5.9	.352		6.0
31	7	.326			.253	.406			6.2	.339		6.1
32	7	.350			.296	.408			5.9	.323		6.3
33	6	.312			.225	.377			6.5	.315		6.4
34	6	.304			.217	.352			6.6	.292		6.4
35	6	.294			.237	.345			6.5	.269		6.5
36	6	.258			.211	.299			5.9	.229		6.4
37	7	.222			.147	.259			7.1	.229		6.4
38	6	.241			.156	.288			6.1	.211		6.5
39	7	.196			.152	.263			6.4	.187		6.8
40	7	.186			.153	.273			6.6	.143		7.0
41	6	.123			.082	.157			8.2	.143		7.0
42	6	.136			.075	.193			6.7	.123		7.2
43	7	.127			.087	.173			6.5	.112		7.3
44	5	.107			.065	.173			7.3	.079		7.8
45	7	.079			.057	.127			8.8	.079		7.9
46	7	.062			.035	.086			8.5	.069		8.1
47	7	.069			.043	.105			7.2	.062		8.1
48	7	.066			.051	.085			7.9	.059		8.2
49	7	.051			.037	.069			8.7	.053		8.7
50	7	.052			.036	.061			9.0	.051		8.7
51	7	.045			.024	.065			9.0	.054		8.7
52	7	.057			.031	.099			8.2	.056		8.7

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: MEDFORD, OREGON Latitude: $42^{\circ} 22'$ N. Elevation: 1321 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Solar week	Years of record	Weekly mean values of daily totals: Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Weekly mean temp.: Mean temperature	Mean max. temp.	Mean cloud cover[1]	Four-week moving mean[2]: Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	10	0.070	35	0.020	0.034	0.096	35	43	8.3	0.070	0.014	8.6
2	10	.068	33	.005	.057	.073	39	46	9.0	.077	.017	8.6
3	10	.078	35	.016	.055	.102	39	46	8.7	.087	.021	8.5
4	10	.093	39	.027	.042	.133	40	48	8.3	.102	.028	8.3
5	10	.108	42	.035	.065	.167	42	51	8.2	.115	.031	8.1
6	10	.127	45	.033	.078	.175	42	52	7.8	.131	.038	8.0
7	10	.131	43	.031	.079	.178	42	51	8.3	.153	.042	7.7
8	10	.159	47	.053	.088	.241	43	52	7.8	.171	.044	7.5
9	10	.197	55	.051	.129	.276	43	54	6.7	.193	.047	7.3
10	10	.197	51	.042	.137	.268	44	55	7.3	.211	.046	7.3
11	10	.221	53	.044	.160	.302	44	55	7.6	.225	.048	7.5
12	10	.231	52	.047	.183	.321	47	59	7.4	.254	.048	7.2
13	10	.252	53	.058	.154	.339	48	59	7.7	.279	.051	7.1
14	10	.313	62	.041	.242	.368	51	65	6.1	.299	.057	7.0
15	10	.319	60	.057	.221	.379	51	64	7.0	.322	.056	6.8
16	10	.314	57	.074	.227	.444	52	66	7.1	.332	.060	6.9
17	10	.342	60	.052	.276	.416	53	66	7.1	.347	.063	6.9
18	10	.355	60	.056	.282	.435	54	68	6.6	.367	.062	6.5

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. MEDFORD, OREGON (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	10	0.375	61	0.070	0.257	0.513	56	70	6.7	0.382	0.071	6.1
20	10	.394	63	.071	.252	.485	60	74	5.7	.400	.072	5.9
21	10	.402	63	.085	.236	.517	58	71	5.5	.408	.073	5.7
22	10	.428	66	.062	.336	.513	62	77	5.7	.415	.067	5.8
23	9	.409	62	.072	.295	.508	63	77	6.1	.429	.062	5.3
24	9	.421	64	.051	.334	.496	62	76	5.9	.434	.055	4.9
25	9	.460	69	.064	.343	.555	67	82	3.3	.451	.047	3.9
26	8	.446	68	.034	.399	.493	65	79	4.1	.463	.045	2.8
27	8	.475	73	.039	.408	.541	70	88	2.2	.465	.041	2.3
28	8	.469	72	.041	.410	.535	74	91	1.7	.466	.043	1.7
29	9	.468	74	.048	.402	.533	74	92	1.1	.456	.039	1.5
30	9	.451	72	.042	.409	.519	74	92	1.6	.449	.036	1.5
31	8	.438	72	.026	.408	.488	72	89	1.8	.434	.031	1.7
32	9	.439	75	.029	.409	.484	74	92	1.3	.413	.029	2.2
33	9	.409	72	.028	.368	.464	71	88	2.1	.396	.029	2.5
34	9	.366	67	.033	.323	.419	68	83	3.6	.369	.031	3.1
35	9	.369	70	.027	.318	.410	68	86	3.1	.341	.038	3.7
36	9	.334	67	.037	.299	.399	69	86	3.4	.322	.041	3.6
37	9	.295	61	.055	.196	.356	65	81	4.5	.297	.049	3.7
38	9	.290	65	.046	.211	.336	63	80	3.4	.273	.053	3.9
39	9	.267	65	.058	.129	.322	63	80	3.4	.248	.049	4.3
40	9	.238	61	.051	.122	.293	60	77	4.5	.222	.041	4.9
41	9	.196	54	.042	.143	.252	56	70	5.7	.196	.035	5.5
42	9	.185	55	.012	.170	.211	55	69	6.0	.173	.032	5.9
43	9	.166	54	.036	.115	.225	51	64	5.9	.153	.030	6.3
44	9	.146	51	.037	.073	.183	48	61	6.2	.129	.033	7.0
45	9	.114	44	.034	.049	.168	47	59	7.3	.110	.033	7.4
46	9	.091	38	.024	.063	.141	41	49	8.5	.092	.028	8.0
47	9	.086	39	.037	.031	.151	42	51	7.7	.083	.026	8.3
48	9	.077	37	.016	.053	.108	40	48	8.5	.074	.023	8.5
49	10	.076	38	.027	.042	.120	38	46	8.5	.066	.020	8.8
50	10	.058	30	.012	.038	.076	39	45	9.2	.063	.019	8.8
51	10	.055	29	.022	.033	.111	39	46	9.0	.062	.017	8.7
52	10	.065	34	.014	.041	.087	36	42	8.5	.064	.015	8.7

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: RAPID CITY, SOUTH DAKOTA   Latitude: 44° 02' N.   Elevation: 3180 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Solar week	Years of record	Weekly mean values of daily totals: Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Weekly mean temp.: Mean temperature	Mean max. temp.	Mean cloud cover[1]	Four-week moving mean[2]: Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	9	0.115	64	0.015	0.095	0.144	27	39	6.0	0.116	0.013	6.5
2	9	.115	61	.014	.097	.148	28	41	7.2	.126	.016	6.7
3	9	.129	63	.012	.109	.147	18	28	6.5	.134	.021	6.9
4	9	.145	65	.022	.118	.187	21	33	7.0	.149	.022	6.7
5	9	.147	61	.034	.101	.201	26	37	6.9	.164	.023	6.7
6	9	.176	67	.019	.153	.204	27	38	6.3	.184	.022	6.6
7	9	.187	64	.017	.167	.224	25	37	6.8	.204	.021	6.6
8	9	.225	71	.018	.195	.246	26	37	6.4	.223	.024	6.5
9	9	.228	66	.031	.163	.283	26	36	6.9	.242	.030	6.5
10	9	.251	67	.030	.212	.300	31	42	6.0	.255	.038	6.7
11	9	.263	65	.041	.206	.338	30	41	6.8	.274	.040	6.7
12	9	.279	64	.052	.185	.349	37	49	6.9	.288	.042	7.1
13	9	.302	65	.038	.217	.354	40	53	7.1	.306	.040	6.9
14	9	.307	62	.037	.261	.351	40	52	7.6	.322	.042	6.8
15	9	.337	65	.033	.291	.374	43	56	6.1	.328	.046	6.9
16	9	.342	62	.059	.266	.448	46	59	6.4	.331	.054	6.7
17	9	.327	58	.054	.245	.410	45	56	7.5	.340	.065	6.8
18	9	.319	54	.071	.234	.457	49	60	6.8	.343	.071	6.7

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. RAPID CITY, SOUTH DAKOTA (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.373	61	0.074	0.271	0.466	55	68	6.3	0.355	0.065	6.5
20	9	.351	56	.084	.188	.429	56	68	6.4	.374	.058	6.3
21	9	.376	59	.033	.313	.421	59	72	6.5	.378	.056	6.3
22	9	.394	61	.042	.335	.457	62	75	6.2	.380	.053	6.4
23	9	.392	60	.065	.295	.470	64	77	6.1	.401	.056	6.0
24	8	.359	54	.070	.287	.484	66	78	6.7	.401	.065	5.6
25	8	.436	66	.047	.379	.499	67	80	4.9	.409	.056	5.0
26	10	.416	63	.078	.247	.538	71	85	4.6	.421	.048	4.4
27	10	.425	65	.029	.348	.476	71	85	3.7	.413	.047	4.2
28	10	.407	63	.036	.330	.448	74	88	4.3	.403	.037	4.1
29	10	.402	63	.045	.331	.456	74	88	4.1	.384	.041	4.5
30	10	.377	61	.038	.306	.429	76	91	4.4	.378	.039	4.5
31	10	.350	58	.047	.275	.409	75	88	5.0	.366	.037	4.6
32	9	.381	65	.027	.330	.424	72	86	4.3	.367	.035	4.4
33	9	.358	64	.037	.284	.401	73	87	4.6	.368	.032	4.1
34	9	.378	70	.031	.328	.417	74	88	3.7	.358	.033	4.1
35	9	.356	69	.032	.297	.389	70	85	4.0	.345	.031	3.9
36	9	.338	69	.030	.292	.379	67	82	4.0	.321	.034	4.2
37	9	.309	67	.030	.263	.355	66	81	3.9	.300	.037	4.1
38	9	.280	65	.043	.198	.323	59	73	4.9	.279	.040	4.1
39	9	.273	68	.046	.183	.323	58	72	3.8	.260	.043	4.2
40	9	.254	68	.040	.199	.306	55	69	3.7	.244	.040	4.1
41	9	.234	68	.045	.128	.272	54	68	4.4	.222	.034	4.4
42	9	.213	67	.030	.144	.251	52	66	4.4	.198	.032	5.0
43	9	.185	63	.022	.166	.227	45	57	5.1	.180	.025	5.3
44	9	.162	61	.033	.107	.198	41	53	6.0	.160	.024	5.8
45	9	.160	66	.016	.125	.184	38	51	5.7	.145	.023	6.1
46	9	.133	60	.023	.097	.158	33	44	6.4	.135	.017	6.0
47	9	.125	61	.017	.010	.153	36	47	6.5	.121	.016	6.3
48	9	.123	64	.011	.108	.139	29	42	5.6	.117	.013	6.1
49	9	.099	58	.012	.091	.128	27	38	6.8	.113	.012	6.0
50	9	.115	66	.012	.093	.130	28	39	5.4	.108	.012	6.1
51	9	.107	62	.013	.089	.128	30	41	6.2	.111	.013	5.9
52	9	.105	60	.011	.094	.129	31	43	6.1	.111	.013	6.4

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: BROWNSVILLE, TEXAS — Latitude: $25^{\circ} 54'$ N. — Elevation: 48 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.			Four-week moving mean 2/		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean max. temp.	Mean cloud cover 1/	Radiation	Standard deviation	Cloud cover
		In./day	Pct. 3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	8	0.161	46	0.067	0.065	0.252	61	70	6.1	0.179	0.046	6.3
2	8	.200	55	.047	.148	.286	62	72	5.4	.189	.052	6.1
3	8	.208	55	.030	.166	.249	60	70	6.3	.202	.051	6.0
4	8	.186	48	.063	.093	.300	61	71	6.7	.209	.052	6.0
5	8	.214	53	.063	.105	.289	63	73	5.6	.216	.050	5.8
6	8	.226	54	.052	.148	.299	64	74	5.5	.212	.048	6.2
7	8	.238	54	.021	.215	.281	65	75	5.5	.221	.044	6.3
8	8	.171	37	.054	.117	.288	62	71	8.2	.230	.041	6.5
9	9	.250	52	.049	.171	.330	66	75	6.2	.234	.052	7.0
10	9	.261	52	.039	.210	.333	67	76	6.3	.270	.049	6.3
11	9	.252	48	.068	.140	.363	68	76	7.2	.272	.049	6.6
12	9	.316	58	.038	.270	.377	69	79	5.3	.284	.048	6.5
13	9	.259	46	.052	.173	.307	70	79	7.5	.290	.051	6.3
14	9	.307	53	.033	.252	.357	74	83	5.8	.285	.064	6.7
15	9	.278	47	.081	.142	.375	71	80	6.7	.297	.061	6.5
16	9	.297	50	.091	.078	.394	74	82	6.7	.308	.071	6.5
17	8	.309	51	.040	.264	.365	78	85	7.0	.331	.062	6.1
18	8	.348	57	.071	.200	.419	77	85	5.5	.347	.054	5.8

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. BROWNSVILLE, TEXAS (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	8	0.370	59	0.048	0.314	0.454	78	86	5.0	0.363	0.060	5.4
20	8	.360	57	.056	.261	.428	79	87	5.8	.379	.054	5.1
21	8	.372	59	.066	.303	.490	81	89	5.3	.387	.053	5.1
22	8	.414	65	.047	.366	.496	81	90	4.2	.398	.056	4.9
23	8	.404	63	.044	.341	.460	83	90	5.2	.401	.054	4.7
24	8	.401	62	.067	.265	.473	83	91	4.8	.400	.058	5.1
25	7	.387	60	.057	.322	.495	83	91	4.7	.406	.061	4.8
26	8	.410	64	.064	.355	.548	82	91	5.5	.403	.053	4.7
27	8	.426	66	.057	.355	.494	83	92	4.3	.411	.048	4.8
28	8	.390	61	.033	.335	.428	83	92	4.4	.411	.043	4.6
29	8	.418	66	.037	.375	.486	84	93	4.9	.408	.036	4.7
30	8	.410	65	.042	.339	.461	84	94	4.9	.413	.041	4.5
31	9	.412	67	.030	.356	.467	85	93	4.4	.404	.042	4.4
32	8	.410	67	.053	.322	.471	85	94	3.7	.387	.047	4.7
33	9	.382	63	.042	.342	.473	85	93	4.7	.370	.052	4.9
34	9	.342	58	.061	.243	.423	84	92	5.9	.340	.057	5.5
35	9	.347	60	.050	.267	.441	84	92	5.1	.324	.057	5.6
36	9	.289	51	.075	.200	.405	81	89	6.5	.318	.051	5.3
37	9	.319	58	.044	.255	.375	81	90	4.8	.312	.048	5.1
38	9	.318	59	.038	.263	.386	82	91	4.9	.309	.046	4.8
39	9	.321	62	.037	.273	.383	80	89	4.2	.300	.052	4.7
40	9	.280	56	.065	.148	.344	78	87	5.3	.288	.057	4.8
41	9	.282	59	.069	.160	.391	77	86	4.5	.274	.061	4.9
42	9	.271	59	.059	.188	.348	74	83	5.3	.258	.056	5.1
43	9	.264	60	.050	.204	.341	73	83	4.5	.236	.048	5.5
44	9	.211	50	.045	.115	.269	72	80	6.0	.215	.040	5.8
45	9	.198	49	.036	.134	.264	66	75	6.2	.200	.038	6.1
46	8	.188	48	.029	.129	.223	70	78	6.5	.190	.038	6.3
47	8	.203	54	.042	.144	.274	66	76	5.6	.186	.039	6.2
48	8	.167	46	.046	.094	.212	62	71	7.0	.187	.043	5.7
49	8	.185	52	.040	.119	.236	65	74	5.7	.181	.045	5.9
50	8	.194	55	.045	.129	.261	59	69	4.6	.177	.043	5.9
51	8	.180	52	.048	.094	.228	63	73	6.1	.171	.049	6.0
52	8	.148	42	.037	.101	.217	61	70	7.3	.173	.050	6.2

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: FORT WORTH, TEXAS — Latitude: 32° 49' N. — Elevation: 706 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Weekly mean values of daily totals: Possible rad.	(5) Weekly mean values of daily totals: Standard deviation	(6) Weekly mean values of daily totals: Minimum radiation	(7) Weekly mean values of daily totals: Maximum radiation	(8) Weekly mean temp.: Mean temperature	(9) Weekly mean temp.: Mean maximum temp.	(10) Mean cloud cover1/	(11) Four-week moving mean2/: Radiation	(12) Four-week moving mean2/: Standard deviation	(13) Four-week moving mean2/: Cloud cover
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	10	0.179			0.103	0.251			5.2	0.171		5.6
2	10	.170			.083	.353			6.1	.172		6.1
3	10	.167			.085	.246			6.4	.173		6.4
4	9	.171			.063	.230			6.9	.185		6.2
5	9	.183			.073	.257			6.3	.198		6.1
6	9	.219			.142	.305			5.3	.208		6.0
7	9	.221			.163	.293			5.7	.224		5.9
8	9	.209			.150	.323			6.7	.234		6.0
9	10	.247			.197	.319			5.7	.248		6.1
10	10	.257			.169	.337			6.0	.276		5.7
11	10	.278			.199	.378			6.2	.295		5.7
12	10	.322			.212	.441			4.9	.318		5.3
13	9	.255			.261	.355			5.5	.329		5.2
14	11	.348			.276	.420			4.4	.331		5.5
15	11	.324			.235	.458			5.9	.331		5.7
16	11	.331			.177	.480			6.0	.335		5.9
17	11	.322			.132	.457			6.3	.343		5.9
18	11	.363			.223	.476			5.6	.353		5.8

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

TABLE A1. FORT WORTH, TEXAS (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	11	.357			.251	.477			5.6	.371		5.5
20	11	.371			.295	.462			5.8	.385		5.4
21	11	.392			.234	.492			5.2	.402		5.0
22	11	.420			.351	.538			4.9	.423		4.3
23	11	.424			.350	.513			4.1	.432		3.9
24	11	.457			.377	.504			3.2	.437		3.6
25	11	.426			.165	.528			3.5	.440		3.5
26	11	.443			.341	.508			3.6	.433		3.9
27	10	.433			.332	.526			3.9	.427		4.1
28	10	.430			.277	.516			4.3	.422		4.2
29	10	.399			.245	.516			4.7	.420		4.1
30	10	.424			.315	.497			4.0	.414		3.9
31	10	.419			.383	.460			3.4	.418		3.5
32	10	.416			.355	.465			3.4	.411		3.3
33	10	.414			.361	.495			3.3	.401		3.3
34	10	.396			.301	.437			3.2	.387		3.2
35	10	.379			.319	.446			3.3	.374		3.3
36	10	.360			.276	.428			3.2	.354		3.5
37	10	.359			.289	.444			3.3	.337		3.7
38	10	.317			.198	.407			4.1	.337		3.9
39	10	.310			.263	.399			4.0	.299		3.9
40	10	.276			.182	.330			4.4	.291		3.7
41	10	.293			.139	.367			3.2	.273		3.7
42	10	.283			.202	.365			3.2	.256		4.0
43	9	.240			.165	.319			4.2	.241		4.1
44	10	.210			.127	.279			5.3	.219		4.6
45	10	.230			.132	.271			3.7	.210		4.6
46	9	.196			.123	.252			5.3	.204		4.4
47	10	.205			.134	.284			4.0	.192		4.7
48	10	.184			.123	.231			4.5	.186		4.5
49	8	.182			.133	.211			4.9	.175		5.1
50	8	.175			.093	.233			4.8	.170		5.2
51	8	.153			.115	.176			6.3	.169		5.3
52	8	.170			.132	.226			4.8	.168		5.6

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: MIDLAND, TEXAS — Latitude: 31° 56' N. — Elevation: 2885 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Possible rad.	(5) Standard deviation	(6) Minimum radiation	(7) Maximum radiation	(8) Weekly mean temp.: Mean temp.	(9) Mean maximum temp.	(10) Mean cloud cover 1/	(11) Four-week moving mean 2/: Radiation	(12) Standard deviation	(13) Cloud cover
		In./day	Pct. 3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	7	0.184	61	0.038	0.130	0.231	44	57	4.6	0.187	0.031	4.6
2	7	.185	60	.037	.121	.228	45	58	5.3	.191	.035	5.3
3	7	.201	62	.021	.160	.224	40	54	5.0	.195	.035	5.8
4	7	.194	58	.043	.140	.256	43	57	6.5	.208	.033	5.7
5	7	.198	56	.039	.135	.236	45	58	6.3	.220	.040	5.7
6	7	.241	64	.028	.211	.288	46	59	4.9	.232	.045	5.5
7	7	.248	62	.048	.163	.304	51	65	5.0	.253	.046	5.1
8	8	.240	57	.063	.156	.316	47	59	6.0	.271	.053	5.2
9	8	.285	64	.047	.193	.336	51	65	4.7	.287	.054	5.4
10	8	.311	67	.056	.195	.362	54	69	5.2	.313	.050	5.0
11	8	.313	64	.050	.255	.378	51	65	5.8	.332	.045	5.0
12	8	.345	67	.049	.262	.398	56	71	4.2	.345	.039	4.8
13	7	.361	67	.025	.309	.391	58	73	4.8	.356	.041	4.5
14	7	.362	65	.033	.310	.415	61	75	4.3	.366	.044	4.9
15	7	.357	62	.055	.283	.419	59	72	4.8	.375	.051	4.9
16	8	.385	65	.063	.247	.463	67	81	5.5	.383	.058	5.1
17	8	.396	66	.053	.301	.465	70	84	5.0	.390	.057	5.1
18	7	.392	64	.062	.343	.519	67	81	5.1	.397	.052	4.8

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week; for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. MIDLAND, TEXAS (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	6	0.387	62	0.048	0.312	0.440	71	85	4.9	0.404	0.048	4.4
20	6	.414	65	.044	.364	.496	73	86	4.1	.406	.047	4.5
21	7	.425	66	.037	.375	.478	74	87	3.4	.419	.041	4.2
22	7	.399	62	.059	.290	.466	77	89	5.6	.422	.049	4.0
23	7	.439	67	.025	.411	.470	79	92	3.6	.425	.047	4.0
24	8	.424	65	.077	.249	.492	81	93	3.3	.433	.042	3.7
25	8	.438	67	.025	.407	.479	81	94	3.4	.329	.050	3.8
26	8	.431	66	.040	.352	.484	81	93	4.5	.429	.045	4.1
27	7	.420	65	.059	.358	.510	81	93	4.0	.422	.055	4.3
28	7	.428	66	.056	.360	.502	81	93	4.3	.415	.054	4.5
29	7	.407	64	.067	.306	.494	81	93	4.6	.414	.044	4.4
30	7	.404	64	.033	.364	.456	82	94	5.1	.408	.042	4.2
31	7	.417	67	.021	.380	.438	83	95	3.7	.404	.035	4.0
32	7	.404	66	.047	.334	.453	82	94	3.5	.399	.034	4.0
33	6	.393	66	.040	.349	.467	82	93	4.6	.390	.034	3.9
34	6	.375	65	.026	.343	.413	80	92	4.3	.385	.030	3.8
35	7	.389	69	.021	.365	.420	81	94	3.3	.376	.031	3.6
36	7	.377	69	.033	.343	.436	77	90	3.1	.366	.032	3.1
37	7	.362	68	.043	.299	.411	76	89	2.6	.340	.043	3.3
38	7	.335	66	.031	.300	.375	77	90	3.3	.317	.045	3.8
39	7	.284	58	.065	.175	.337	73	84	4.4	.297	.046	4.2
40	7	.288	62	.040	.237	.331	70	83	4.9	.278	.056	4.4
41	7	.280	63	.049	.196	.345	68	80	4.2	.268	.053	4.3
42	7	.260	62	.071	.155	.331	63	75	4.0	.254	.054	4.1
43	7	.244	62	.052	.146	.303	60	73	4.0	.243	.053	3.8
44	6	.233	62	.045	.165	.284	56	67	4.1	.234	.041	3.9
45	6	.235	66	.044	.151	.282	52	64	3.2	.228	.032	3.7
46	6	.224	66	.022	.193	.250	54	68	4.1	.222	.026	3.7
47	7	.221	69	.016	.198	.235	50	64	3.3	.207	.026	4.1
48	7	.208	67	.021	.187	.248	47	61	4.0	.198	.026	4.0
49	7	.175	58	.045	.120	.220	48	61	4.8	.191	.027	4.5
50	7	.187	64	.023	.159	.220	43	56	4.0	.189	.029	4.4
51	7	.194	67	.020	.167	.217	47	60	5.2	.187	.027	4.3
52	7	.184	63	.029	.149	.222	44	58	3.6	.187	.031	4.7

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: PROSSER, WASHINGTON Latitude: 46° 15' N. Elevation: 840 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Solar:	Years:	Weekly mean values of daily totals					Weekly mean temp.		Mean	Four-week moving mean[2]		
week	of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean maximum temp.	cloud cover[1]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	4	0.057	35	0.010	0.043	0.066	29	36		0.074	0.017	
2	4	.080	47	.008	.073	.089	34	41		.080	.020	
3	4	.094	51	.023	.060	.112	30	38		.093	.024	
4	3	.088	44	.039	.043	.111	29	37		.102	.034	
5	3	.110	52	.026	.095	.140	32	40		.115	.032	
6	3	.114	47	.047	.059	.143	36	44		.134	.024	
7	3	.149	55	.017	.139	.169	37	46		.158	.032	
8	4	.162	54	.007	.153	.168	39	48		.177	.031	
9	4	.207	62	.055	.129	.255	38	50		.202	.035	
10	3	.191	53	.046	.147	.238	39	50		.224	.046	
11	4	.249	64	.031	.222	.287	41	53		.243	.038	
12	3	.249	59	.052	.191	.290	45	58		.265	.039	
13	3	.282	62	.021	.263	.305	46	58		.290	.040	
14	4	.282	59	.052	.220	.346	48	62		.323	.040	
15	4	.347	68	.035	.294	.371	49	63		.348	.045	
16	5	.380	71	.050	.307	.421	50	64		.378	.042	
17	5	.384	68	.045	.326	.440	51	65		.397	.045	
18	5	.404	68	.037	.363	.436	54	68		.407	.048	

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. PROSSER, WASHINGTON (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	4	0.419	70	0.048	0.359	0.472	57	71		0.419	0.057	
20	4	.422	68	.064	.333	.476	60	74		.430	.065	
21	4	.431	69	.080	.322	.496	59	73		.434	.070	
22	3	.450	70	.067	.376	.505	62	77		.435	.059	
23	4	.435	67	.067	.370	.530	63	78		.451	.044	
24	4	.424	67	.023	.414	.470	64	78		.456	.040	
25	4	.497	75	.019	.481	.523	65	81		.467	.036	
26	4	.469	71	.050	.426	.541	63	79		.476	.037	
27	4	.477	73	.052	.407	.531	67	83		.477	.035	
28	4	.460	72	.027	.436	.491	73	90		.481	.032	
29	4	.502	80	.009	.493	.513	71	90		.477	.028	
30	4	.485	79	.041	.423	.510	70	88		.478	.025	
31	4	.460	77	.033	.419	.488	69	87		.458	.030	
32	4	.465	81	.017	.442	.481	70	89		.425	.035	
33	4	.420	76	.031	.378	.454	69	86		.405	.034	
34	4	.355	67	.060	.311	.443	66	83		.375	.036	
35	4	.380	75	.027	.352	.415	64	80		.348	.036	
36	4	.346	73	.024	.314	.368	64	81		.336	.024	
37	4	.312	70	.032	.276	.343	65	81		.309	.023	
38	4	.307	73	.015	.290	.322	60	76		.283	.025	
39	4	.270	70	.020	.240	.285	59	74		.254	.024	
40	4	.244	68	.033	.209	.275	55	71		.218	.031	
41	4	.196	60	.028	.161	.227	53	66		.191	.038	
42	4	.160	53	.045	.104	.209	53	66		.163	.038	
43	4	.163	60	.046	.111	.206	48	60		.138	.040	
44	4	.135	54	.035	.105	.177	45	57		.104	.033	
45	4	.094	42	.035	.065	.141	42	52		.102	.026	
46	4	.092	45	.019	.066	.108	37	46		.083	.027	
47	4	.089	47	.015	.074	.103	38	47		.079	.021	
48	4	.057	35	.038	.021	.096	33	40		.074	.019	
49	4	.077	44	.012	.062	.091	33	42		.067	.017	
50	4	.073	43	.010	.058	.081	35	42		.069	.014	
51	4	.060	35	.007	.051	.067	34	40		.064	.014	
52	4	.065	38	.028	.027	.093	33	39		.065	.013	

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: SPOKANE, WASHINGTON   Latitude: 47° 37' N.   Elevation: 2387 feet

(1) Solar week	(2) Years of record	(3) Weekly mean values of daily totals: Radiation	(4) Possible rad.	(5) Standard deviation	(6) Minimum radiation	(7) Maximum radiation	(8) Weekly mean temp.: Mean temperature	(9) Mean max. temp.	(10) Mean cloud cover1/	(11) Four-week moving mean2/: Radiation	(12) Standard deviation	(13) Cloud cover
		In./day	Pct.3/	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	6	0.059	40	0.027	0.022	0.095	25	30	9.1	0.067	0.026	8.6
2	6	.069	44	.019	.051	.105	30	35	8.9	.075	.024	8.4
3	7	.088	51	.028	.042	.119	24	30	7.4	.085	.024	8.1
4	7	.085	45	.023	.061	.118	25	31	8.2	.094	.031	8.1
5	7	.100	48	.025	.068	.139	26	33	8.1	.105	.034	8.3
6	7	.102	44	.047	.050	.176	32	37	8.6	.119	.035	8.4
7	7	.131	51	.041	.075	.182	31	37	8.3	.139	.038	8.2
8	7	.143	50	.027	.109	.184	33	40	8.6	.159	.037	8.0
9	7	.177	56	.038	.134	.234	30	38	7.4	.181	.039	7.8
10	7	.183	53	.042	.126	.240	33	40	7.8	.202	.044	7.6
11	7	.223	59	.051	.147	.284	37	45	7.3	.212	.041	7.9
12	7	.227	55	.046	.173	.285	41	51	7.9	.244	.042	7.7
13	7	.215	49	.025	.175	.250	42	50	8.6	.259	.041	7.6
14	7	.311	65	.047	.239	.369	45	56	6.8	.276	.041	7.6
15	7	.284	57	.046	.223	.370	46	56	7.2	.304	.041	7.2
16	7	.296	56	.046	.235	.365	46	56	7.7	.309	.043	7.3
17	7	.326	59	.026	.291	.371	47	57	7.2	.329	.043	7.3
18	7	.328	57	.053	.239	.387	50	61	7.3	.342	.058	6.9

1/ Mean of hourly observations from sunrise to sunset.
2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.
3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1, SPOKANE, WASHINGTON (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	7	0.364	61	0.048	0.304	0.438	53	65	6.8	0.358	0.064	6.7
20	7	.348	56	.106	.190	.480	55	66	6.3	.380	.069	6.4
21	7	.391	62	.049	.312	.463	57	69	6.3	.393	.078	6.3
22	7	.418	65	.071	.288	.497	62	74	6.3	.399	.086	6.3
23	6	.413	63	.086	.337	.535	61	73	6.2	.415	.085	6.1
24	6	.372	56	.138	.095	.464	62	74	6.2	.416	.085	6.0
25	5	.457	69	.043	.411	.523	66	79	5.7	.422	.076	5.8
26	5	.421	64	.072	.359	.512	62	75	6.0	.442	.052	5.1
27	6	.440	68	.050	.388	.516	64	77	5.4	.446	.047	4.0
28	6	.451	70	.043	.391	.506	73	87	3.1	.452	.038	3.3
29	6	.474	76	.023	.446	.503	76	91	1.5	.441	.043	2.9
30	6	.445	73	.037	.378	.489	72	86	3.2	.433	.039	2.9
31	6	.395	66	.068	.299	.464	68	81	4.0	.416	.039	3.2
32	6	.418	73	.028	.365	.443	71	86	3.0	.389	.044	3.5
33	6	.407	74	.023	.367	.428	68	81	2.6	.371	.036	3.8
34	6	.337	64	.056	.262	.395	66	79	4.5	.346	.041	4.2
35	6	.323	65	.036	.287	.386	63	76	5.0	.312	.046	4.9
36	7	.318	68	.049	.238	.403	63	77	4.8	.290	.044	5.3
37	7	.271	62	.045	.214	.335	62	75	5.1	.266	.046	5.5
38	7	.250	62	.048	.164	.296	55	66	6.1	.235	.046	5.8
39	7	.227	60	.043	.180	.290	55	67	5.9	.207	.047	6.3
40	7	.194	56	.046	.101	.247	52	63	6.2	.183	.042	6.6
41	7	.159	51	.049	.101	.253	48	58	7.2	.159	.046	6.9
42	7	.151	53	.031	.095	.183	48	58	7.0	.141	.043	6.8
43	7	.130	50	.056	.063	.215	43	51	7.2	.126	.037	6.9
44	7	.123	53	.036	.059	.167	40	49	5.8	.109	.034	7.1
45	7	.100	47	.026	.058	.133	38	46	7.4	.096	.028	7.2
46	7	.080	42	.019	.050	.104	29	36	8.1	.081	.026	7.7
47	7	.080	47	.032	.050	.130	36	43	7.4	.072	.026	8.1
48	7	.064	41	.029	.035	.118	30	35	8.1	.069	.026	8.0
49	7	.063	43	.024	.045	.104	29	35	8.7	.063	.027	8.3
50	7	.069	48	.021	.046	.113	31	37	7.7	.060	.027	8.5
51	7	.056	40	.033	.033	.125	31	36	8.7	.059	.028	8.6
52	7	.051	36	.031	.018	[illegible]	29	33	8.9	.059	.028	8.9

TABLE A1.--Weekly mean values of daily total solar and sky radiation (short wave) expressed in inches per day evaporation equivalent (1 gram of water = 590 calories), percent of possible radiation, mean and mean maximum temperatures, and mean cloud cover. Obtained from U. S. Weather Bureau Records. Elevations generally are the height of the instruments.

LOCATION: LANDER, WYOMING   Latitude: 42° 48' N.   Elevation: 5574 feet

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		Weekly mean values of daily totals					Weekly mean temp.		Mean	Four-week moving mean[2]		
Solar week	Years of record	Radiation	Possible rad.	Standard deviation	Minimum radiation	Maximum radiation	Mean temperature	Mean max. temp.	cloud cover[1]	Radiation	Standard deviation	Cloud cover
		In./day	Pct.[3]	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
1	7	.148	76	0.017	0.115	0.169	21	32	5.2	0.144	0.016	5.5
2	8	.138	68	.021	.108	.169	27	37	6.1	.149	.019	5.7
3	7	.157	72	.011	.143	.173	19	31	5.7	.156	.022	5.9
4	8	.155	67	.026	.093	.176	23	35	5.9	.171	.021	5.7
5	8	.172	68	.031	.107	.217	24	36	5.8	.187	.024	5.9
6	8	.201	73	.016	.185	.235	24	37	5.6	.207	.025	6.1
7	8	.221	73	.023	.194	.253	28	40	6.2	.229	.028	6.1
8	8	.235	71	.030	.176	.275	26	38	6.8	.253	.035	5.9
9	8	.261	73	.042	.195	.333	24	35	5.6	.275	.037	5.8
10	8	.294	76	.044	.227	.364	30	43	4.8	.296	.035	5.7
11	8	.309	74	.030	.264	.358	29	41	6.1	.293	.031	5.9
12	8	.321	72	.025	.285	.357	36	48	6.1	.322	.030	6.3
13	8	.313	66	.027	.263	.349	38	51	6.8	.341	.030	6.3
14	8	.347	69	.037	.268	.388	38	51	6.6	.355	.040	6.3
15	9	.382	72	.031	.332	.439	40	53	5.6	.368	.046	6.4
16	9	.376	68	.065	.245	.445	45	58	6.1	.377	.050	6.3
17	8	.367	64	.050	.286	.441	44	57	7.2	.376	.063	6.6
18	8	.382	64	.056	.282	.440	49	61	6.3	.386	.067	6.4

1/ Mean of hourly observations from sunrise to sunset.

2/ Value given is for the end of the solar week, for solar week No. 1 the value is the mean of weeks 52, 1, 2, 3, etc.

3/ Percent of extra-terrestrial radiation for given latitude and season of the year.

TABLE A1. LANDER, WYOMING (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		In./day	Pct.	In./day	In./day	In./day	Deg.F.	Deg.F.	Tenths	In./day	In./day	Tenths
19	9	0.380	62	0.083	0.214	0.487	52	65	6.7	0.393	0.067	6.3
20	9	.417	66	.079	.255	.501	53	66	5.5	.404	.058	6.1
21	9	.394	61	.051	.317	.499	55	68	6.5	.420	.049	5.8
22	9	.428	66	.021	.398	.470	57	70	5.8	.426	.043	5.7
23	8	.440	67	.037	.383	.497	61	75	5.4	.442	.043	5.1
24	8	.441	67	.063	.316	.528	63	77	5.0	.455	.053	4.6
25	8	.458	69	.050	.385	.524	66	82	4.1	.464	.058	4.1
26	9	.483	73	.063	.361	.587	67	83	4.0	.461	.051	3.9
27	9	.473	72	.058	.366	.545	68	84	3.1	.459	.050	3.8
28	9	.431	67	.035	.387	.492	71	86	4.4	.442	.044	3.9
29	9	.451	71	.045	.367	.531	72	88	3.6	.425	.038	4.3
30	9	.415	67	.039	.351	.472	73	88	4.3	.418	.037	4.2
31	9	.404	66	.030	.358	.444	72	87	4.7	.399	.038	4.5
32	9	.401	68	.034	.362	.456	71	86	4.0	.392	.034	4.4
33	8	.375	66	.047	.308	.449	70	85	4.9	.389	.032	4.2
34	8	.388	71	.024	.361	.434	69	84	4.1	.379	.036	4.2
35	8	.394	76	.024	.349	.433	66	82	3.9	.371	.039	3.8
36	8	.360	73	.049	.283	.452	65	81	3.8	.353	.047	3.8
37	8	.340	73	.061	.236	.400	62	77	3.5	.325	.054	3.8
38	8	.315	71	.055	.232	.376	56	71	3.9	.311	.051	3.6
39	8	.285	69	.051	.189	.333	55	69	4.1	.291	.046	3.7
40	8	.303	79	.036	.245	.334	54	69	2.9	.271	.042	3.8
41	8	.263	74	.043	.177	.311	51	65	3.9	.251	.038	3.9
42	8	.233	71	.038	.156	.275	49	63	4.4	.220	.037	4.5
43	8	.204	68	.035	.149	.246	42	55	4.4	.197	.032	5.0
44	8	.180	65	.032	.136	.230	37	49	5.4	.179	.029	5.4
45	8	.171	67	.024	.127	.209	35	47	5.8	.169	.024	5.6
46	7	.160	68	.026	.125	.198	28	40	6.1	.160	.019	5.5
47	7	.163	75	.013	.148	.181	31	43	5.2	.152	.016	5.3
48	8	.148	73	.013	.129	.163	24	36	5.1	.146	.015	5.1
49	8	.138	71	.014	.122	.157	24	35	4.7	.137	.017	5.2
50	8	.136	72	.021	.101	.167	26	37	5.3	.133	.017	5.2
51	8	.126	68	.019	.094	.157	28	40	5.6	.135	.018	5.3
52	8	.132	71	.014	.106	.153	22	34	5.1	.136	.018	5.5

TABLE A2.--Summary of mean values of monthly total solar and sky radiation (short wave) expressed in inches evaporation equivalent (1 gram water = 590 calories). Computed from weekly mean values obtained from U. S. Weather Bureau records. Elevations generally are the height of the instruments

LOCATION: PHOENIX, ARIZONA
Latitude: 33° 26' N. - Elev.: 1139 feet

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	9	6.22	0.61	4.93	7.03
Feb.	9	7.64	.67	6.60	8.50
Mar.	9	11.02	.62	10.34	11.91
Apr.	9	13.16	.58	12.52	13.88
May	9	15.17	.50	14.49	15.99
June	8	14.93	.59	14.32	15.94
July	9	13.80	.59	12.77	14.72
Aug.	9	12.78	.55	12.05	13.35
Sept.	9	11.41	.57	10.48	12.35
Oct.	8	9.26	.85	7.69	10.21
Nov.	8	6.91	.40	6.14	7.48
Dec.	9	5.93	.15	4.94	6.46

LOCATION: DAVIS, CALIFORNIA
Latitude: 38° 32' N. - Elev.: 50 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Mimimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	9	3.33	0.52	2.38	4.23
Feb.	8	4.85	1.01	3.49	6.44
Mar.	8	8.40	.79	7.18	9.22
Apr.	9	10.77	.67	9.53	11.45
May	9	13.32	.71	12.09	13.99
June	8	14.31	.57	13.30	15.00
July	9	14.43	.37	13.87	15.13
Aug.	9	12.91	.19	12.60	13.22
Sept.	9	10.08	.30	9.48	10.47
Oct.	8	7.23	[illegible]	6.24	7.89
Nov.	8	4.32	[illegible]	3.07	5.63
Dec.	7	3.15	[illegible]	2.15	[illegible]

LOCATION: FRESNO, CALIFORNIA
Latitude: 36° 46' N. - Elev.: 362 ft.

Jan.	9	3.86	0.63	2.75	4.67
Feb.	9	5.49	1.0[illegible]	4.81	7.43
Mar.	9	9.10	1.01	7.77	11.00
Apr.	9	10.90	.76	10.18	12.48
May	9	12.93	1.0[illegible]	11.63	14.62
June	8	14.04	1.21	12.58	15.81
July	9	13.81	1.35	11.61	15.93
Aug.	9	12.66	1.20	11.11	14.58
Sept.	9	10.36	1.04	8.85	11.90
Oct.	9	7.94	.91	6.88	9.18
Nov.	9	5.03	.54	4.13	5.86
Dec.	9	3.56	.64	2.78	4.67

LOCATION: GRAND JUNCTION, COLORADO
Latitude: 39° 07' N.- Elev.: 4[illegible]8 ft.

Jan.	9	4.90	0.42	4.48	5.89
Feb.	9	6.13	.70	5.04	6.89
Mar.	8	9.11	1.22	7.27	11.27
Apr.	8	10.75	1.05	9.36	12.25
May	6	12.62	.97	11.55	14.39
June	6	14.20	.62	13.30	15.08
July	7	14.02	.89	12.39	15.33
Aug.	7	12.55	.77	11.15	13.30
Sept.	6	10.22	.85	8.74	11.17
Oct.	8	7.85	1.02	5.86	9.24
Nov.	9	5.31	.43	4.49	5.94
Dec.	9	4.45	.38	3.83	4.91

LOCATION: BOISE, IDAHO
Latitude: 43° 34' N. - Elev.: 2895 feet

Jan.	7	2.97	0.52	2.36	3.83
Feb.	7	4.24	.67	3.51	5.48
Mar.	8	7.09	.57	6.46	7.92
Apr.	8	9.63	.65	8.35	10.24
May	9	12.04	.70	11.08	13.04
June	8	12.96	1.03	11.35	14.58
July	9	13.86	.67	12.91	14.86
Aug.	9	12.09	.54	11.50	13.13
Sept.	9	9.29	.67	8.14	10.22
Oct.	9	6.36	.81	5.13	7.89
Nov.	8	3.64	.65	2.67	4.56
Dec.	9	2.64	.47	1.85	3.22

LOCATION: DODGE CITY, KANSAS
Latitude: 37° 46' N. - Elev.: 2625 ft.

Jan.	8	5.42	0.63	4.51	6.43
Feb.	8	6.14	.84	5.07	7.27
Mar.	8	8.66	1.30	6.41	10.56
Apr.	8	10.60	1.38	8.64	11.91
May	8	11.82	.97	10.25	12.92
June	7	13.24	.78	12.23	14.17
July	9	13.43	1.11	12.29	15.39
Aug.	8	12.42	.83	11.66	14.26
Sept.	8	10.15	.86	9.03	11.74
Oct.	8	7.93	1.18	5.55	9.16
Nov.	8	5.77	.63	4.53	6.35
Dec.	8	4.96	.33	4.31	5.16

TABLE A2.--Continued

LOCATION: GLASGOW, MONTANA
Latitude: 48° 13' N. - Elev.: 2294 feet

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	6	3.18	0.31	2.61	3.37
Feb.	6	4.80	.27	4.40	5.21
Mar.	5	8.07	.39	7.74	8.73
Apr.	5	9.46	.55	9.01	10.39
May	6	11.83	.79	10.60	13.34
June	4	11.98	.38	11.71	12.53
July	3	12.71	.19	12.57	12.92
Aug.	7	11.52	.92	10.63	12.77
Sept.	8	8.07	.69	7.05	9.41
Oct.	6	5.47	.90	4.85	7.25
Nov.	6	3.31	.74	2.64	4.72
Dec.	6	2.38	.17	2.24	2.70

LOCATION: GREAT FALLS, MONTANA
Latitude: 47° 29' N. - Elev.: 3692 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	7	2.92	0.41	2.43	3.49
Feb.	7	4.45	.47	3.90	5.25
Mar.	6	7.34	.56	6.66	8.01
Apr.	7	8.86	.59	7.91	9.64
May	7	10.85	.76	9.92	12.30
June	7	11.93	.78	10.80	13.19
July	5	12.74	1.38	11.08	14.12
Aug.	7	11.53	.76	10.78	12.72
Sept.	7	8.41	.81	7.60	9.55
Oct.	9	5.53	.86	4.02	6.69
Nov.	8	3.18	.38	2.65	3.60
Dec.	8	2.48	.37	2.00	2.95

LOCATION: ELY, NEVADA
Latitude: 39° 17' N. - Elev.: 6262 feet

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	6	4.90	0.29	4.44	5.24
Feb.	6	6.16	.41	5.88	6.96
Mar.	8	9.60	.94	8.07	10.71
Apr.	8	11.38	.56	10.45	12.08
May	9	12.96	.99	11.33	14.53
June	9	14.29	.71	13.18	15.12
July	8	13.79	.43	13.16	14.27
Aug.	10	12.84	.70	11.62	13.60
Sept.	10	10.59	.68	9.07	11.22
Oct.	9	8.24	.91	6.67	9.37
Nov.	9	5.71	.43	5.09	6.31
Dec.	9	4.55	.20	4.17	4.78

LOCATION: BISMARCK, NORTH DAKOTA
Latitude: 46° 46' N. - Elev.: 1677 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	9	3.29	0.22	3.01	3.68
Feb.	9	4.75	.22	4.25	5.03
Mar.	9	7.49	.52	6.77	8.22
Apr.	9	9.04	.54	8.12	9.84
May	9	11.52	.92	10.23	13.17
June	9	11.72	.80	[illegible].31	12.68
July	9	12.82	.94	[illegible].60	14.04
Aug.	9	10.85	.52	9.78	11.52
Sept.	9	7.95	.70	7.07	9.12
Oct.	9	5.72	.82	3.85	6.62
Nov.	9	3.19	.28	2.83	3.65
Dec.	9	2.60	.27	2.27	3.08

LOCATION: STILLWATER, OKLAHOMA
Latitude: 36° 08' N. - Elev.: 910 feet

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	7	4.25	0.75	3.36	5.40
Feb.	7	5.23	.83	4.00	6.25
Mar.	8	8.14	.75	7.46	9.30
Apr.	7	9.53	.75	8.24	10.17
May	7	10.24	.82	9.11	11.34
June	7	12.18	.82	11.18	13.11
July	6	11.69	1.52	9.14	13.29
Aug.	8	11.28	.72	10.46	12.67
Sept.	7	9.57	1.42	7.45	11.78
Oct.	6	7.08	.97	6.20	8.80
Nov.	7	5.29	.72	4.14	6.47
Dec.	8	4.46	.60	3.21	5.26

LOCATION: ASTORIA, OREGON
Latitude: 46° 09' N. - Elev.: 22 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	7	2.03	0.35	1.66	2.68
Feb.	6	2.93	.64	2.11	4.01
Mar.	7	5.56	.75	4.27	6.81
Apr.	5	7.51	1.10	6.05	9.07
May	5	10.26	1.17	8.83	12.07
June	7	9.43	.85	8.19	10.81
July	7	11.07	1.14	9.25	12.08
Aug.	6	9.84	1.24	7.66	11.04
Sept.	5	7.18	.73	6.14	7.98
Oct.	4	4.72	1.15	3.47	6.26
Nov.	5	2.15	.36	1.77	2.74
Dec.	7	1.59	.16	1.43	1.82

TABLE A2.--Continued

LOCATION: CORVALLIS, OREGON
Latitude: 44° 33' N. - Elev.: 236 feet

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	1	2.45	-	-	-
Feb.	0	-	-	-	-
Mar.	2	5.44	0.10	5.40	5.48
Apr.	3	8.00	.74	7.56	8.85
May	3	10.62	1.21	9.45	11.86
June	1	10.72	-	-	-
July	1	13.86	-	-	-
Aug.	3	11.88	.68	11.42	12.66
Sept.	2	7.31	.94	6.66	7.97
Oct.	2	4.82	.25	4.66	4.98
Nov.	2	2.77	.64	2.33	3.22
Dec.	2	1.59	.10	1.55	1.63

LOCATION: MEDFORD, OREGON
Latitude: 42° 22' N. - Elev. 1321 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches
Jan.	10	2.49	0.27	2.20	2.92
Feb.	10	3.93	.54	3.18	4.83
Mar.	10	6.84	.71	5.45	7.97
Apr.	10	9.62	.99	8.06	11.07
May	10	12.04	1.20	10.35	13.95
June	8	12.99	1.22	11.05	14.42
July	8	14.36	1.09	13.28	16.16
Aug.	8	12.53	.34	12.05	13.04
Sept.	9	9.04	.74	7.88	9.84
Oct.	9	5.93	.71	4.69	6.90
Nov.	9	3.01	.44	2.36	3.87
Dec.	9	1.99	.35	1.60	2.57

LOCATION: RAPID CITY, SOUTH DAKOTA
Latitude: 44° 02' N. - Elev.: 3180 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
Jan.	9	3.97	0.36	3.46	4.46
Feb.	9	5.39	.26	5.03	5.83
Mar.	9	8.28	.87	6.85	9.20
Apr.	9	9.81	.68	8.74	10.58
May	9	11.20	1.09	9.66	12.99
June	8	11.99	1.05	10.75	13.89
July	10	12.40	.76	11.57	13.27
Aug.	9	11.35	.05	10.43	11.99
Sept.	9	9.11	.67	7.64	10.31
Oct.	9	6.69	.80	4.85	7.40
Nov.	9	4.18	.06	3.93	4.52
Dec.	9	3.38	.06	3.06	3.49

LOCATION: BROWNSVILLE, TEXAS
Latitude: 25° 54' N. - Elev.: 48 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
Jan.	8	5.94	1.22	4.66	8.36
Feb.	8	6.05	.80	4.61	7.20
Mar.	9	8.36	1.03	6.88	9.63
Apr.	8	8.94	1.09	6.77	10.11
May	8	11.46	.84	10.38	13.24
June	7	12.04	1.18	10.30	13.86
July	8	12.75	.94	11.39	14.11
Aug.	8	11.73	.97	10.94	13.87
Sept.	9	9.42	.91	7.87	10.73
Oct.	9	8.31	1.33	6.09	10.65
Nov.	8	5.80	.51	5.05	6.67
Dec.	8	5.43	.82	4.08	6.25

LOCATION: FORT WORTH, TEXAS
Latitude: 32° 49' N. - Elev.: 706 ft.

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
Jan.	9	5.26	0.90	3.98	7.33
Feb.	9	6.04	1.12	4.53	8.34
Mar.	9	8.79	1.12	7.09	9.92
Apr.	9	9.89	1.60	6.91	12.01
May	11	11.70	1.24	9.23	13.48
June	11	13.23	1.18	12.12	15.29
July	10	13.10	1.20	10.74	14.72
Aug.	10	12.58	.98	11.45	13.97
Sept.	10	10.19	1.41	8.12	12.10
Oct.	9	8.34	1.29	6.16	10.20
Nov.	9	6.23	.92	4.49	7.75
Dec.	8	5.29	.73	4.53	5.76

LOCATION: MIDLAND, TEXAS
Latitude: 31° 56' N. - Elev.: 2855'

MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
Jan.	7	5.94	0.61	5.30	6.96
Feb.	7	6.75	.76	5.44	8.01
Mar.	7	10.08	1.05	8.58	11.37
Apr.	6	11.25	.27	11.08	11.72
May	5	12.53	.53	11.93	13.19
June	7	12.90	.64	11.56	13.55
July	7	12.88	1.32	11.42	15.01
Aug.	5	12.24	.49	11.38	12.52
Sept.	7	10.29	.97	8.67	11.57
Oct.	6	8.20	.99	6.62	9.66
Nov.	6	6.73	.36	6.13	7.11
Dec.	7	5.79	.53	5.08	6.32

TABLE A2.--Continued

LOCATION: SPOKANE, WASHINGTON Latitude: 47° 37' N. - Elev.: 2387 ft.						LOCATION: LANDER, WYOMING Latitude: 42° 48' N. - Elev.: 5574 ft.				
MONTH	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum	Length of record	Av. evap. equiv.	Std. dev.	Minimum	Maximum
	Years	Inches	Inches	Inches	Inches	Years	Inches	Inches	Inches	Inches
Jan.	6	2.40	0.46	2.12	3.35	6	4.70	0.24	4.58	5.21
Feb.	7	3.57	.86	2.38	4.98	8	6.07	.29	5.78	6.55
Mar.	7	6.42	.77	5.48	7.83	8	9.39	.77	8.28	10.57
April	7	9.06	.59	8.13	9.70	7	11.00	.73	9.83	11.97
May	7	11.37	.78	10.19	12.85	8	12.34	1.14	9.77	13.48
June	5	13.01	.92	11.62	14.09	8	13.55	.95	11.71	14.71
July	5	13.88	.51	13.29	14.59	9	13.68	1.18	12.24	15.42
Aug.	6	11.72	.89	10.40	13.08	8	12.14	.40	11.61	12.77
Sept.	6	8.10	.84	6.24	8.51	8	9.89	1.22	7.96	11.02
Oct.	7	4.81	1.07	3.80	6.69	8	7.56	.68	6.83	8.52
Nov.	7	2.64	.49	1.89	3.50	7	4.91	.26	4.50	5.21
Dec.	7	1.85	.73	1.34	3.44	8	4.15	.36	3.48	4.65

APPENDIX B

Examples of data sheets, (No. 1 and No. 2), used for obtaining detailed evapotranspiration data from field locations.

Data Sheet No. 1
(To be completed for each experiment)

Evapotranspiration and Soil Moisture
Extraction Data Obtained by the
Western Soil and Water Management Research Branch
Soil and Water Conservation Division
U. S. Department of Agriculture

CROP: ____________ Variety: ____________ Measurements made by: ____________
LOCATION: ____________ City ____________ State ____________
ELEVATION: ________ feet above sea level. LATITUDE: ________ ° ________ 'N
SOIL TYPE: ____________ Max. rooting depth for this crop & soil. How measured ____________
SOIL MOISTURE CHARACTERISTICS:

Depth	Field Capacity		Wilting Point		Bulk Density	Available Water	Depth	Field Capacity		Wilting Point		Bulk Density	Available Water
Ft.	% or In.		% or In.		gms/cm	In.	Ft.	% or In.		% or In.		gms/cm	In.
0-___	___	___	___	___	___	___	___-___	___	___	___	___	___	___
___-___	___	___	___	___	___	___	___-___	___	___	___	___	___	___
___-___	___	___	___	___	___	___	___-___	___	___	___	___	___	___
___-___	___	___	___	___	___	___	___-___	___	___	___	___	___	___
___-___	___	___	___	___	___	___	___-___	___	___	___	___	___	___

How were their values determined? ____________

WATER TABLE: Approximate depth during cropping season ______ ft; Offseason ______ ft.
TYPE OF IRRIGATION USED: (check one) Furrow__; Corrugation__; Graded Border__; Level Border__; Sprinkler__; Other______
SIZE OF MOISTURE PLOT: ____x____ ft.; No. of reps. sampled____; Row spacing____inches (where applicable)
Description of experimental site relative to surrounding area. (Upwind vegetation or land surface condition such as irrigated, dry farmed, trees, desert, rangeland, etc.) ____________

CLIMATIC DATA AT LOCATION: 1/	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Avg. Max. Temp., °F	___	___	___	___	___	___	___	___	___	___	___	___
Avg. Min. Temp., °F	___	___	___	___	___	___	___	___	___	___	___	___
Avg. Temp., °F	___	___	___	___	___	___	___	___	___	___	___	___
Avg. Rainfall, Ins.	___	___	___	___	___	___	___	___	___	___	___	___
Avg. Wind Velocity, m.p.h. 2/	___	___	___	___	___	___	___	___	___	___	___	___
Pan Evaporation, Ins. 3/	___	___	___	___	___	___	___	___	___	___	___	___
Sunshine Data 4/												
Avg. Possible hrs/day	___	___	___	___	___	___	___	___	___	___	___	___
Avg. Actual hrs/day	___	___	___	___	___	___	___	___	___	___	___	___

1/ Long-time averages, Length of record ________ Years.
2/ Height of anemometer above ground ________ Feet.
3/ Type of pan, USWB ________; Other ________
4/ Obtain from nearest U. S. Weather Bureau.

Evapotranspiration Data Obtained by the
Western Soil and Water Management Research Branch
Soil and Water Conservation Division
U. S. Department of Agriculture

Data Sheet No. 2
(Complete for each optimum and medium treatment sampled)

EVAPOTRANSPIRATION MEASUREMENTS

IRRIGATION LEVEL: Optimum ________ Medium ________ Expt. Code No. ________ Year ________
FERTILIZER APPLIED: N ______ #/ac, P_2O_5 ______ #/A, K ______ #/A, Other ________
DATE PLANTED: Month ________ Day ______ Year ______. HARVESTED: Month ________ Day ______ Year ______
YIELD FOR TREATMENT: ________ per acre. Was this normal? Yes___ No___ 1/ ________
VARIABILITY OF E.T. MEASUREMENTS: Approx. std. deviation of E.T. per sampling site, if available ________ in/day

Irrigation Data			Soil Sampling Data			Climatic Data for each Sampling Period							Crop Data		Evapotranspiration Data				
(1) No.	(2) Date Mo./Day	(3) Amt 2/	(4) Dates Sampled	(5) No. of Sites Sampled	(6) Depth Sampled	(7) Avg. Max. Temp	(8) Avg. Min. Temp.	(9) Avg. Temp.	(10) Rainfall	(11) Wind Movement	(12) Evap. from pan	(13) Gen. Condition 3/	(14) Stage of Growth 4/	(15) Apprx. Plant Ht.	(16) Actual E.T. between sampling dates: Total	(17) Avg.	(18) Estimate of E.T. 5/: Total	(19) Avg.	(20) Accumulative E.T. to end of period 6/
		In.			Ft.	°F	°F	°F	In.	Avg. m.p.h.	In/da			In.	In.	In/da	In.	In/da	In.

1/ If reduced by insects, hail, lodging, etc., indicate date and cause of decrease and expected normal.
2/ Was this water measured? Yes___ No___. How________
3/ Indicate general climatic conditions by numerical index. Foggy or rainy, 1; cloudy 2; partly cloudy, 3; clear, 4; hot and windy, 5.
4/ Tillering, boot, heading, etc. for grains, before cutting, after cutting for hay, etc.
5/ Estimates from sampling date before irrigation to sampling date following irrigation, and other estimates.
6/ Include estimate of E.T. from date of irrigation to first sampling date; also from date of planting to first sampling date.